Massachusetts Bay Transportation Authority
MBTA Contract V7PSO5
UMTA Grant MA - 29 - 9001

FEASIBILITY STUDY FINAL REPORT

BOWDOIN STATION & CHARLES STATION CONNECTOR PROJECT

STV/ Seelye Stevenson Value & Knecht

in association with
CPF/ Domenech & Hicks, Inc.
Comstock Engineering, Inc.
DMC Engineering, Inc.
Haley & Aldrich, Inc.
Multisystems, Inc.

Boston, Massachusetts
DECEMBER, 1986

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STV/SEELYE STEVENSON VALUE & KNECHT

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December 10, 1986

Massachusetts Bay Transportation Authority
10 Park Plaza
Boston, Massachusetts 02116

Attention: Mr. Francis M. Keville
Director, Construction Department

Reference: Bowdoin Station and Charles Station Connector
Project - Feasibility Study
MBTA Contract V7PS05
UMTA Grant MA-29-9001

Dear Mr. Keville:

We are pleased to present the Final Report for the Bowdoin Station and Charles Station Connector Project Feasibility Study.

This report is an expanded version of the report issued in April of this year. It contains a revised station scheme, additional information on ridership and operating cost estimates and incorporates comments received from the MBTA

The results of our evaluation of the basic feasibility of this project can be summarized in three statements:

- The construction of the tunnel extension from the existing Bowdoin Station to a new passenger platform and fare collection area under the Charles Station is feasible using cut and cover construction. This construction should have extensive traffic decking over the excavation areas to facilitate movement of vehicles on Cambridge Street and through Charles Circle.

- Several station, track and tunnel alternatives are viable and are candidates for further development. This report evaluates three schemes for their impact on the urban context of the area, impact on transit users and MBTA operations.

- The impact on the regional transportation system will be favorable. The new station will benefit transit patrons by the addition of an additional transfer station between the only rapid transit lines in the MBTA that do not intersect. The new transfer station will be a significant asset in improving ground access to Logan Airport. Early construction of the station and tunnel extension could provide a component in the overall transportation plan to reduce traffic congestion during the construction of the Third Harbor Tunnel and the Central Artery.

This report describes the results of a study which examined the feasibility of a extending the existing Blue Line tunnel from Bowdoin Street under Cambridge Street westward to Charles Circle station at Charles Circle. The task in this project included identification of all issues relating to conditions at the proposed right-of-way, such as property impacts, environmental aspects, utilities, traffic, pedestrian circulation and construction impacts. Three station and tunnel alternatives have been evaluated. Operational and construction cost estimates have been developed to determine all the elements needed to implement the project. This study also included an analysis of the potential ridership and the results of a separate CTPS ridership study.

The positive statements of feasibility contained in this report is a first step in a program to implement the linkage between the Blue and Red Lines of the MBTA Rapid Transit System

Very truly yours,

STV/SEELYE STEVENSON VALUE & KNECHT, INC.

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MBTA CONTRACT V7PS05 BOWDOIN STATION AND CHARLES STREET STATION
CONNECTOR PROJECT FEASIBILITY STUDY

TABLE OF CONTENTS

LIST OF FIGURES

I. INTRODUCTION

A. Background

The need to make transportation improvements to connect the Blue and Red Lines has existed for a number of years. These two are the only rapid transit lines in the MBTA system that do not intersect. Trips using both of these lines require two transfers. The Bowdoin Station-Charles Street Station Connector project is a long-range proposal to remedy this deficiency by provision of a connection between the Blue and Red Lines at Charles Street Station. The new Blue Line Station would be located at Charles Street Circle below street level with an escalator, stair and elevator connection to the elevated Charles Street Red Line Station.

This transit improvement will benefit communities inside and outside of Boston. The community in the vicinity of the proposed station, including Beacon Hill and the Massachusetts General Hospital (MGH) area, will receive the benefits of increased accessibility to the MBTA. Other Boston communities will benefit from an additional transfer station between subway lines and increased transit accessibility to the Charles Circle Area, the MGH and the recreational areas along the Charles River. A creation of a connection between the Blue and Red Lines at Charles Street will give the MBTA an opportunity to improve access between Red Line communities from Alewife to Braintree, Ashmont and Mattapan in and Blue Line communities from Beacon Hill to Revere . The new transfer station will be a significant asset in improving ground access to Logan Airport from all of these communities.

The recent activity in planning for the Third Harbor Tunnel and the Central Artery has identified the need for improved transit as one of the major components in an overall transportation plan that will reduce traffic congestion during construction of these projects.

B. Work Program

The MBTA authorized the firm of Seelye Stevenson Value & Knecht, Inc. to examine the feasibility of connecting the Blue and Red Lines at Charles Street Station. The study evaluates an extension of the existing Blue Line Tunnel from Bowdoin Street under Cambridge Street westward to Charles Circle. The proposed station location is at Charles Circle with provisions for train turnaround and storage for Blue Line trains. This study provides an analysis of the potential ridership using existing MBTA and CPTS studies. The other tasks in this project include identification of all issues relating to conditions at the proposed right-of-way, such as property impacts, environmental aspects, utilities, traffic, pedestrian circulation and construction impacts. Three station and tunnel alternatives are evaluated. Operational and construction cost estimates are developed to determine all the elements needed to implement the project.

C. Purpose of the Report

The goal of the project is to determine the benefits, costs and the relative impact of three feasible design alternates. The benefits which will be identified include new ridership and transfer ridership. Travel market impacts will be identified including consideration of ground access to Logan Airport, use of Red Line Park-and-Ride Stations, north and south shore travel, and site developments along the Red and Blue Line. The impact of the three following scenarios on ridership are analyzed:

- o Prior to Third Harbor Tunnel and Central Artery Construction
- o During Construction of Third Harbor Tunnel and Central Artery
- o After Construction of Third Harbor Tunnel and Central Artery

Costs are estimated for operations, utility relocations, tunnel and station construction and staging.

Each of the station and tunnel alternates are evaluated for station design and ease of transfer, operational flexibility and construction impacts on the surrounding community.

II. RIDERSHIP AND USER GROUP BENEFITS

A. Current Travel and User Characteristics

The connection of the Blue and Red lines at Charles Street Station will provide direct benefits to those passengers who currently use both lines and potential benefits for all who travel between the Red and Blue line corridors. The Blue Line carried approximately 8 million passengers in 1985 (about 25,000 per average weekday), while the Red Line carried 33 million (over 120,000 per average weekday). Ridership has been growing rapidly, as 1985 showed an increase of about 13% over 1984 on both lines, and this increase does not include the full ridership impact of the Alewife Station, which opened in March of 1985. Ridership data for passengers using both lines for a particular trip are not gathered on an annual basis, but the most recent MBTA Passenger Survey (1979) indicated that about 4400 Blue-Red line round trips are made on an average weekday. These trips consist of work commutation trips and non-work trips (which may be further divided into airport and non-airport trips).

An estimate of total corridor-to-corridor commutation was made using 1980 Census Journey-to-Work tabulations. These data indicate that on the order of 6,000 work trips were made each day on all modes between communities on the Blue Line and communities on the Red Line. Approximately 1,000 of these trips were made on public transportation (including all modes). These commutation trips include trips by residents in East Boston, Revere, and surrounding communities to industries and institutions in the Cambridge-Somerville area, as well as Dorchester-Quincy. A smaller flow of commuters travel from residences along the Red Line to Logan Airport and other places of work in East Boston and Revere.

After commutation trips, trips to and from Logan Airport are the main source of travel between the Red and Blue lines. Based on a 1984 passenger survey conducted by Massport, of the 23,400 passengers travelling to Logan on an average weekday, about 10% (2,300) originate in communities along the Red Line. Cambridge is the most significant source of these trips, with over 1,000 trips to Logan on an average day, using all modes.

Using the 1978 survey estimates of overall and commuter Red-Blue ridership, we find that roughly 65% of this travel is in the peak and 35% is off-peak. Based on the overall percentage of Red-Blue trips to Logan, it would appear that off-peak trips include social/recreational (e.g., to Wonderland, Harvard Square), educational, medical, and personal business trips. Improvements in access for medical trips to the vicinity of Massachusetts General Hospital will be a major benefit (over 75,000 annual trips - approximately 250 trips per day - are made to MGH by in and out-patients living in Blue Line communities). Generally, this category of ridership has a greater sensitivity to travel time savings, then peak Red - Blue ridership.

Many Blue Line passengers with a destination in the area around Charles Station now use Bowdoin Station, choosing to walk rather than make a double transfer to get to the closer Station. Thus, many of the passengers now at Bowdoin who originate on the Blue Line will use the Blue Line Connector to go to Charles.

The Connector will provide alternate subway routes to Government Center and State from Red Line Northwest stations that are competitive with the existing routes (via Park and Washington Stations). Haymarket traffic (coming from the Red Line Northwest) may also be diverted to the Connector, with people using nearby Bowdoin Station instead. The 1984 ridership from Red Line Northwest stations to Government Center, State and Haymarket is about 2100. Current travel for each category of ridership is shown in Exhibit 1.

B. Future Systems Effects and Ridership

1. Transportation System Changes Affecting Ridership

The extension of the Blue Line and connection to the Red Line at Charles Station will provide a major improvement in rapid transit service for passengers needing to use both lines. The current system requires two transfers for Red-Blue trips (either Red-Green-Blue or Red-Orange-Blue), as well as walks and level changes when changing modes. The connection would provide a decrease in travel time by reducing the waiting time in transfers, as well as an increase in the perceived convenience by reducing the walk distance and the anxiety associated with transfers. In order to quantify the inconvenience of the additional walking and waiting involved in a transfer, a "perceived" travel time comparison has been developed.

Travel times calculated for a previous study by the MBTA in 1977 appear to be generally accurate for the current system. These times and calculations of changes in travel time are summarized in Exhibits 2 through 5. These calculations show expected peak-hour travel time (including walk and wait times from Kendall to Aquarium to decrease by about 5 minutes, while the actual time from South Station to Aquarium would increase by 1 minute. However, the "perceived" travel time (where out-of-vehicle time is weighted by a factor of 2.5 and each transfer is penalized by 4 minutes to reflect the additional inconvenience of walk and wait time) would be reduced by 17.5 and 12 minutes to Aquarium from Kendall and South Station. Perceived travel times would be higher during off-peak periods because of generally longer waiting times. Off-peak reductions would be approximately 19 minutes from North and South. Relative travel time reductions would be even more dramatic for trips originating at Charles, because two transfers would be eliminated. The resulting time decrease would be a significant percentage of the total trip.

Passengers diverted from their current downtown station (Bowdoin to Charles) or route (to Government Center, State or Haymarket) would experience smaller travel time savings. Those riding to Charles would save, on average, 6 minutes (minus 8 minute walk, plus 2 minute ride). Those changing their route would experience travel time savings of less than 5 minutes, with some trips experiencing virtually no savings.

Given the travel times available with the Bowdoin-Charles Connector, the diversion rates expected for each ridership group are shown in Exhibit 6. Total diverted ridership is expected to be about 3750 round trips per weekday.

The major alternative mode of travel - the automobile - will also be affected by changes in travel time. Generally, with no change in the highway network, auto travel times will increase as additional traffic causes further congestion. This congestion would be most severe for trips requiring harbor crossing (such as South Shore trips to the airport). Other trips, such as Revere to Cambridge work trips, may avoid the severe congestion associated with the tunnels and bridges, but will still experience some delays over time. The delays would tend to further increase the ridership potential of the rapid transit system with the Bowdoin-Charles Connector, as growth in the total travel market would go disproportionately to the MBTA.

Dramatic changes would result from the Third Harbor Tunnel - Central Artery Project. During THT-CA construction, highway delays are likely to be severe and often unpredictable. This would result in a major diversion of current auto travel to the transit system. Once the project is completed, highway travel times are likely to be reduced enough to attract some people away from transit.

Certain other modes of travel are important to the airport travel market. Massport has introduced boats and park-and-ride express buses to Logan and will continue to market new services in an attempt to reduce auto usage. These changes will also have a direct effect on transit ridership. Generally, measures which are designed to attract people from cars will also attract people from transit. At the same time, measures which make auto use less convenient would tend to increase transit use. Also, the airport parking situation will greatly affect that market. Restrictions on parking supply and increased prices will increase all other modes of travel to Logan.

2. Regional Growth and Development

More general changes will be occurring in population and location trends. As the Massachusetts and Boston economies grow, employment will increase region wide, requiring increased tripmaking of all kinds. As described above, this growth will force certain transportation issues, requiring major changes in the system or significant shifts in travel patterns. Because the highway system is closer to capacity than the transit system (for the markets affected by the Connector Project), growth would tend to favor the transit system.

At the same time, specific economic development projects in the areas around MBTA stations will have a more direct effect on the ridership potential. Significant projects have been identified, including the Kendall Square, Cambridgeport, and Alewife areas in Cambridge; the Charles Circle and Waterfront areas in Boston; the piers and Bird Island Flats in East Boston; and Revere Beach in Revere. Given the proximity of these developments to Red or Blue Line Stations, they are likely to generate significant new ridership and growth potential for the two lines and the connector.

In addition, the growth of the regional economy will cause increases in both freight and passenger traffic through Logan Airport, resulting in increases in passenger and employee trips. Again, this growth can be accommodated more readily by the rapid transit system (with the connector in place) than by the highway system, until the Third Harbor Crossing is completed.

C. Projected Ridership

Ridership is projected for three scenarios related to the Third Harbor Tunnel - Central Artery (THT-CA) Project: 1) without THT-CA, 2) during construction of THT-CA, and 3) with THT-CA. Ridership is projected using two methodologies -- an elasticity-based estimate and a UCPS model. The elasticity-based estimate looks at incremental changes in the system (such as changes in travel times or employment) and estimates the likely effects of each change. The projected ridership will reflect the cumulative impact of all changes on the system, guided by bounds on the overall impact (e.g., transit ridership in a specific market segment should not exceed a certain percentage of the total market. The UTPS model, developed by CTPS, uses parameters that are input to revise the transit network to include the connector. The model predicts ridership on segments of the Blue Line based on the relative attractiveness of transit compared to the automobile (under the three highway scenarios). The two methodologies serve as checks for each other to assure that reasonable results are obtained.

1. Elasticity-Based Forecast

The travel time reductions that will apply to each group of riders are summarized in Exhibit 7. Low and high estimates of ridership increases were made using travel time elasticities applied to these changes in equivalent perceived travel time. The elasticities (low/high) were -0.2/-0.7 for

the peak, and -0.2/-0.9 for the off-peak. The range is wide because published data show a wide variation, from -0.1 to -1.1 (with these values applied to actual time savings). The higher value is used in the off-peak because discretionary trips are believed to be more sensitive. If the Blue Line connector induces significant change in resident/workplace patterns (e.g. because a perceived travel barrier against living in the Blue Line area is removed for people working in Cambridge), still higher elasticities might be expected.

The forecast calculations are shown in Exhibit 8. The low/high estimates of new riders (weekday, round trip, 1984 level) without the THT-CA is 269/835.

Because of the particular sensitivity of Logan travelers to transfers, trips to and from Logan were studied separately. It is believed that current elasticity measures would not capture the full effect of reducing transfers for airport trips (given the importance of arriving on time and the difficulty of transferring while carrying baggage).

The ridership forecast was based on comparisons of mode split between the Red Line area and the two areas with better transit access, downtown and Brookline. Different modal diversion rates were applied to different modes and trip purposes. For example, Cambridge has the same number of transit trips to Logan as Brookline, but has 5 times as many taxi trips. These taxi trips were considered expecially vulnerable to diversion. High and low estimates of modal diversion were made, and are included in Table 8. The forecasted increases (low/high) are 142/323 round trips, representing an increase of 22%/49% over current Red Line - Airport. Overall transit modal share from Red Line communities would increase from 22% to 27%/33% (low/high), representing an increase in Blue Line use to the Airport from 6.5% to 7%/7.5%.

Using the low/high elasticities of 0.2/0.8, ridership increases were calculated for the passengers diverted from other downtown stations. Because travel time savings are much lower, the expected increase in ridership is much lower (about 10-50 for people using Charles instead of Bowdoin, and 25-100 for those travelling between Red Line-north stations and Government Center and State (GC/State).

The existing and new volumes for the three major markets - Logan travel, Red-Blue corridor passengers, and downtown diversions are summarized in Exhibit 9. This shows a base year (1984) total ridership on Bowdoin-Charles Connector of 4000 to 4600 weekday round trip passengers. The ridership on the connector represents approximately one-sixth of the boarding counts at the existing 10 stations on the Blue Line. Annual ridership is estimated to be 2.3 to 2.7 million one-way trips.

With the institution of the Connector, many passengers will no longer have to transfer at one or two of the major downtown stations (Park, Washington, Government Center and State). This will relieve congestion within the stations, we well as reduce crowding on trains between certain stations (particularly on the Green Line between Park and government Center). Detailed flow projections are shown in Exhibit 10.

a. Effects of Third Harbor Tunnel-Central Artery Project

During the long period (10 or more years) of construction for the THT-CA, highway delays are likely to be severe and often unpredictable. This would result in a major diversion of current auto travel to the transit system. Increases in Connector ridership to Logan from the base year volumes are predicted to be on the order of 50%, with increases for the Red-Blue corridors at 20% to 25%, and increases for downtown diversion riders to be 10-20% (see Exhibit 10). Overall, the increased ridership on the Connector would be on the order of 20%, or 700 round trips per weekday.

Once the project is completed, highway travel times are likely to be reduced enough to attract some people away from transit. This would result in a net decrease in transit ridership potential. However, many users who switched to the Connector may continue to use transit, resulting in no net decrease from pre-THT-CA levels. The exception to this would be Logan travel, as a new express bus from South Station may prove to be a very attractive transit alternative. If the travel time from South Station in the THT-CA is on the order of 10-15 minutes to the airport (as predicted) and no premium fare is charged, the diversion from the connector would be quite high. If a premium fare is charged, or the bus does not serve each terminal directly, many Red Line riders from the North and some from the South will still use the Blue Line. For purposes of this analysis, 60% of Red-North users and 80% of Red-South riders are assumed to be diverted to the South Station Shuttle. This will reduce total weekday ridership by about 10% from base year levels, to about 3900 (see Exhibit 11).

b. Effects of Regional Development

Plans for developments in the Red-Blue corridors (Cambridge, downtown Boston, and East Boston) were reviewed. Expected new trips to be generated by 1990 were developed using those plans. In addition, projections of Logan travel and regional growth were obtained. Based on projected growth rates from 1990 to 2010, expansion factors were applied to generate estimated trip-making in 2010. Exhibit 11 shows expected ridership in 2010 on the Connector both with

and without the THT-CA project. These figures shown overall ridership growth of 20% to 25% over base year estimates, if the THT-CA is not constructed.

2. Ridership Estimate Based on UTPS Model

In addition to the elasticity-based ridership estimates, a separate analysis was conducted by CTPS, using UPTS-based models. This modelling effort was carried out to provide a check on the more intuitive elasticity estimate and to point out systemwide effects that the micro-level analysis might miss.

The model was used to forecast a 2010 trip table for the region. This forecast was based on a 1975 trip table, adjusted using FRATAR expansion and incorporating recent changes in the transit system (Red Line extensions). Airport trips were extracted from a 1979 survey of passengers and employees. For 2010, updated projections of population, employment, airport activity, and regional development were used.

The model used an all-or-nothing assignment to project 2010 weekday ridership on the connector. Exhibits 12 and 13 show the ridership forecast for all downtown links, without the THT-CA project and with the THT-CA. The Bowdoin-Charles link forecasts are approximately 50% above the 2010 estimates based on elasticity. However, the base year estimates do not differ by as much. The model estimate appears to incorporate more fully the effects of regional development and recent transit capital improvements. As a result, the model projections diverge from the elasticity projections more in future years.

The estimate of Bowdoin-Charles ridership after THT-CA construction (7000 weekday round trips) includes an increase of 2300 one-way trips on the transit system over the total ridership without the connector. Thus, the connector would result in increased ridership, as well as travel time savings to current riders. The overall ridership and travel time effects are summarized in Exhibit 14.

D. Summary of Impacts

1. Higher Level of Service

The Bowdoin-Charles Connector will provide large travel time savings to riders who use both the Blue and Red Lines, as well as time savings and increased travel options for passengers destined for certain downtown stations.

2. Increased Transit use

Because of the travel time savings and improved convenience, transit usage in the Red and Blue line corridors will increase.

3. Airport Access

The Connector will provide much better transit access from communities served by the Red Line, increasing transit ridership from these areas by 25%-50%. Given the rapid growth projected for airport travel, it will provide a critical link for improved access.

4. Reduced Downtown Subway Congestion

Because of the Connector, many passengers will no longer have to transfer at one or two of the major downtown stations (Park, Washington, Government Center, and State). This will relieve congestion within the stations, as well as reduce crowding on trains between certain stations (particularly on the Green Line between Park and Government Center).

5. New Development

The Bowdoin-Charles Connector will serve and promote new development in Cambridge, East Boston, revere, Charles Circle, and the Waterfront by improving access between locations not well-served by the existing rapid transit system. With the improved access between Cambridge and East Boston/Revere, barriers to current location decisions may be removed.

6. Third Harbor Tunnel - Central Artery Construction

If the Connector is in place prior to THT-CA construction, it will provide a much-needed alternative to driving for people who travel between communities served by the Red Line and Blue Line (particularly Logan travel and South Shore travel).

7. New Ridership and Rapid Transit Diversion

Ridership passing through the new station is estimated to be one-sixth of the total Blue Line ridership. A peak in ridership of three million annual trips on the connector is estimated to occur during construction of the Third Harbor Tunnel and Central Artery.

EXHIBIT 1

1984 BASE O-D TABLE: WEEKDAY ROUND TRIPS
(1978 MBTA Survey Expanded to 1984 - Averaged)

	Bowdoin	GC/State	Blue-E	Logan*	Haymarket
Red-N	62	1654	682	446	430
Charles	0	16	67	11	8
Bowdoin	-	55	1321	177	NA
Red-S	150	NA	665	160	NA

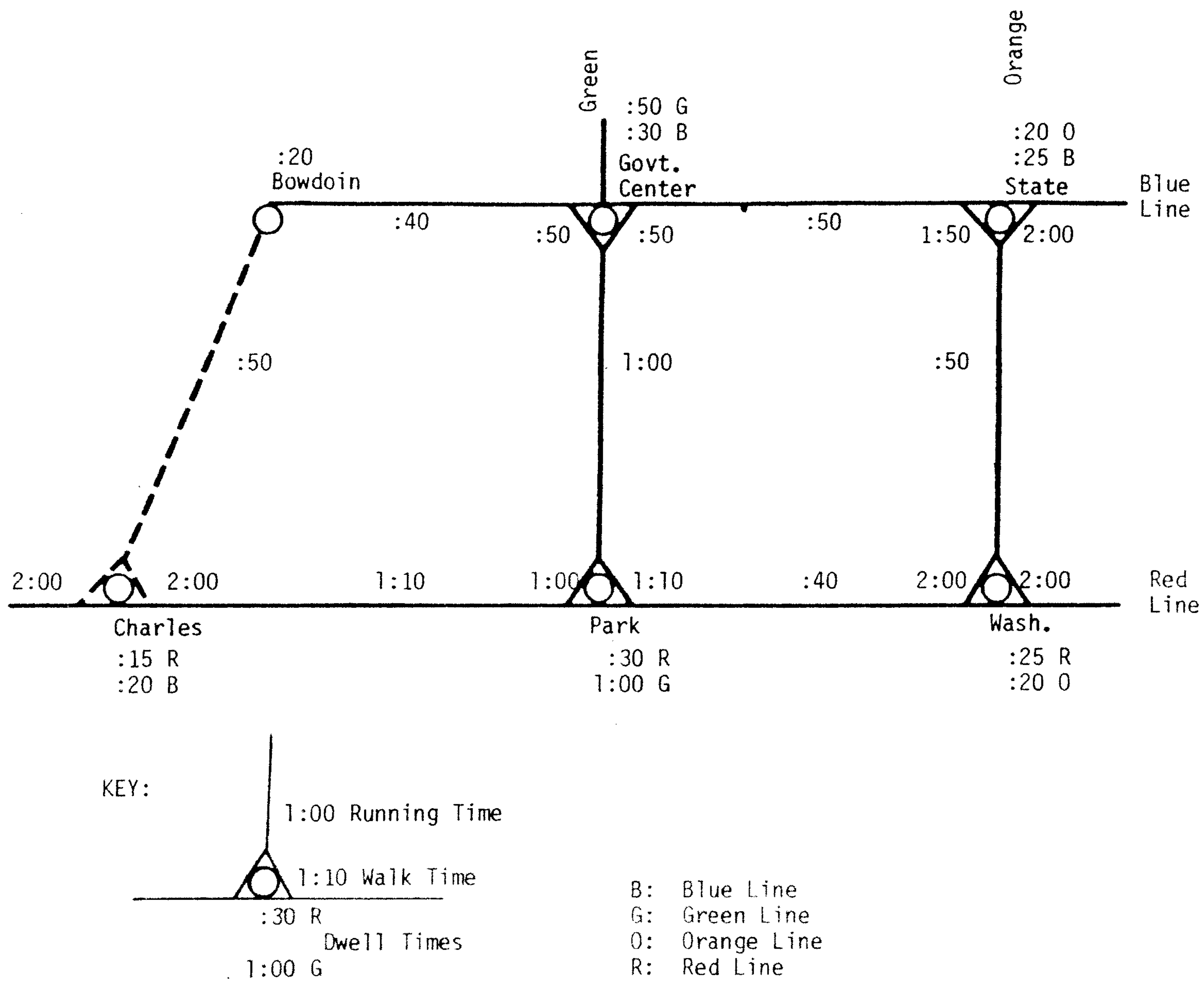
* For Red Line - Logan travel, 1984 Massport Survey was used. Values based on 1978 MBTA survey were virtually identical.

Key to Abbreviations

Red-N: Red Line stations north and west of Charles.
Red-S: Red Line stations south and west of Washington.
GC/State: Government Center and State stations.
Blue-E: Blue Line stations east of State.

EXHIBIT 2

ESTIMATED TRAVEL TIME
EXCLUDING ESTIMATED WAIT TIME
(Minutes: Seconds)



Source: MBTA 1977 Travel Time Savings Analysis

EXHIBIT 3

ASSUMPTIONS MADE IN CALCULATING TRAVEL TIME CHANGES

1. Travel time consists of wait, board, ride, stop, alight, and walk times. In calculating perceived equivalent time, excess time, consisting of wait, board, alight, and walk time, plus ride time on the Green and Orange Lines, is multiplied by 2.5. In addition, a transfer penalty of 4 minutes is added to perceived equivalent travel time for each transfer.

2. Alighting time = 1/3 of dwell time; boarding time = full dwell time.

3. Average experienced wait time = (H/2) (1 + v2), where H = average headway and v = ratio or headway standard deviation to average headway. For the Green Line, v = 1.0 in peak, 0.9 off-peak; for the Red, Blue and Orange Lines, v = 0.32.

4. Average headways, and consequent average experienced wait time, are as follows: (the long Green Line peak headway is because many trains do not serve the Park Street - Government Center link and because of occasional long gaps in service).

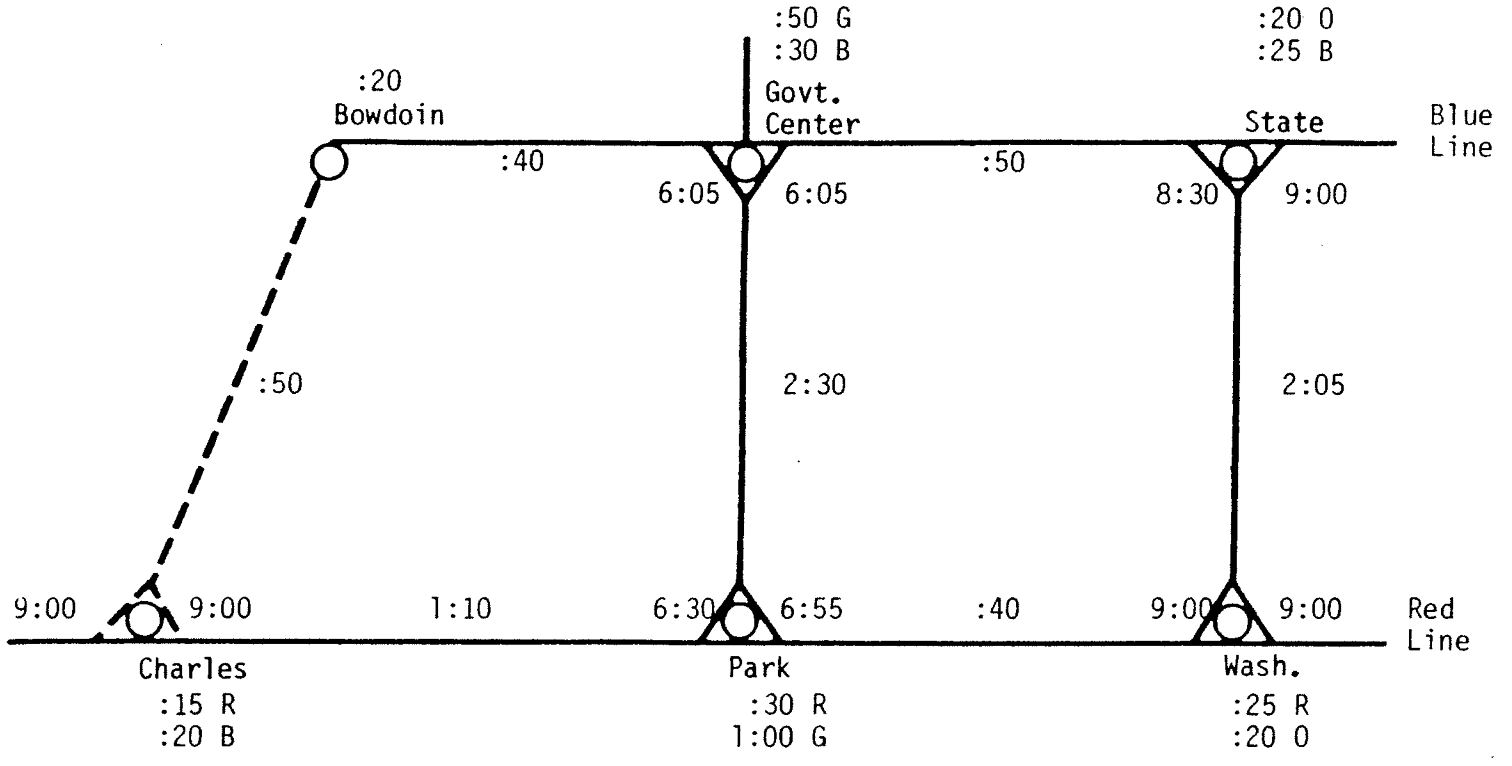
	Green Line		Orange Line	
	Hdwy	Wait Time = WG	Hdwy	Wait Time = WO
peak	3 min	3.0 min	4 min	2.2 min
off-peak	4 min	3.6 min	9 min	5.0 min

5. Running times, dwell times, and walk times are given on the map shown in Exhibit 2. Running times and dwell times were further increased by 20% on the Green Line and by 10% on all other lines.

6. When a figure differs by direction (e.g. walk time at Park St.), an average is used.

EXHIBIT 4

PERCEIVED EQUIVALENT TRAVEL TIME (P.E.T.T.)
EXCLUDING ESTIMATED WAIT TIME
(Minutes: Seconds)



NOTE:
P.E.T.T. = 1 x travel time + 2.5 x (out-of vehicle time) + 4 min. transfer penalty

EXHIBIT 5

ESTIMATED TRAVEL TIMES, RED LINE TO BLUE LINE
(Minutes)

	Travel Time	Perceived Equivalent Travel Time
KENDALL - STATE		
Before	9.3+WB+WG	25.2+2.5WB+2.5WG
After	7.5+WB	15.2+2.5WB
Change	-1.8-WG	-10.0-2.5WG
Change, Peak	-4.8	-17.5
Change, off pk	-5.4	-19.0
SO. STATION-AQUARIUM		
Before	7.9+WB+WO	24.9+2.5 WB+2.5 WO
After	11.0+WB	15.2+2.5 WB
Change	+3.1-WO	-6.2-2.5 WO
Change, Peak	+0.9	-11.7
Change, off pk	-1.9	-18.6

NOTE: WG, WB, WO = average experienced wait time on Green, Blue and Orange Line, respectively.

EXHIBIT 6

TRIPS DIVERTED TO CONNECTOR
(1984 Weekday Round Trips)

	Bowdoin	GC/State	Blue-E	Logan	Haymt*	Total
Red-N	100% 62	60% 992	100% 682	100% 446	38% 129	2311
Charles	100% 0	100% 16	100% 67	100% 11	40% 3	97
Bowdoin**	NA 0	0% 0	33 436	33% 58	NA 0	494
Red-S	100% 150	0% 0	85% 565	90% 144	NA 0	859
Total	212	1008	1750	659	132	3761

* Red Line - Haymarket passengers diverted to Bowdoin.

** Blue Line - Bowdoin passengers diverted to Charles.

EXHIBIT 7

CHANGE IN EQUIVALENT PERCEIVED TRAVEL TIME
TIME SAVINGS IN MINUTES
(Weighted Avg. - 60% Peak - 40% Off-Peak)

	Bowdoin	GC/State	Blue-E	Logan	Haymarket
Red-N	20	7.5	18	18	1
Charles	NA	NA	30	NA	NA
Bowdoin	NA	NA	18	18	NA
Red-S	17	NA	14	14	NA

NOTE:
NA - Not Applicable, if diverted demand is low.

EXHIBIT 8

LOW AND HIGH RIDERSHIP INCREASE ESTIMATE
(Weekday Round Trips - 1984 Base)

	Bowdoin		GC/State		Blue-E		Logan		Haymt		Total	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Red-N	6%	24%	3%	10%	5%	19%	24%	55%	-	-		
	4	15	24	96	33	131	105	245	0	0	166	487
Charles	-	-	-	-	10%	38%	24%	55%	-	-		
	0	0	0	0	6	25	3	6	0	0	9	31
Bowdoin	-	-	-	-	7%	29%	24%	55%	-	-		
	0	0	0	0	31	126	14	32	0	0	45	158
Red-S	6%	22%	-	-	4%	15%	14%	28%	-	-		
	8	33	0		21	86	20	40	0	0	49	159
Total	12	48	24	96	91	386	142	323	0	0	269	835

NOTE: Based on elasticities of -0.2 and -0.8 applied to P.E.T.T., except Logan calculated based on similar zone modal splits.

EXHIBIT 9

DIVERTED AND NEW RIDERS USING CONNECTOR
(Weekday Round Trips - 1984 Base)

	Diverted From other MBTA Lines	New Riders (from Elasticity)		Est. Total	
		Low	High	Low	High
Logan Travel	660	140	320	800	980
Red-Blue Corridors	1530	70	290	1600	1820
Downtown Diversion	1580	50	220	1630	1800
Total	3770	260	830	4030	4600
Approx. Annual O.W. Trips				2.3m	2.7m

EXHIBIT 10

FLOW CHANGES DUE TO DIVERSION
(Weekday Round Trips - 1984 Base)

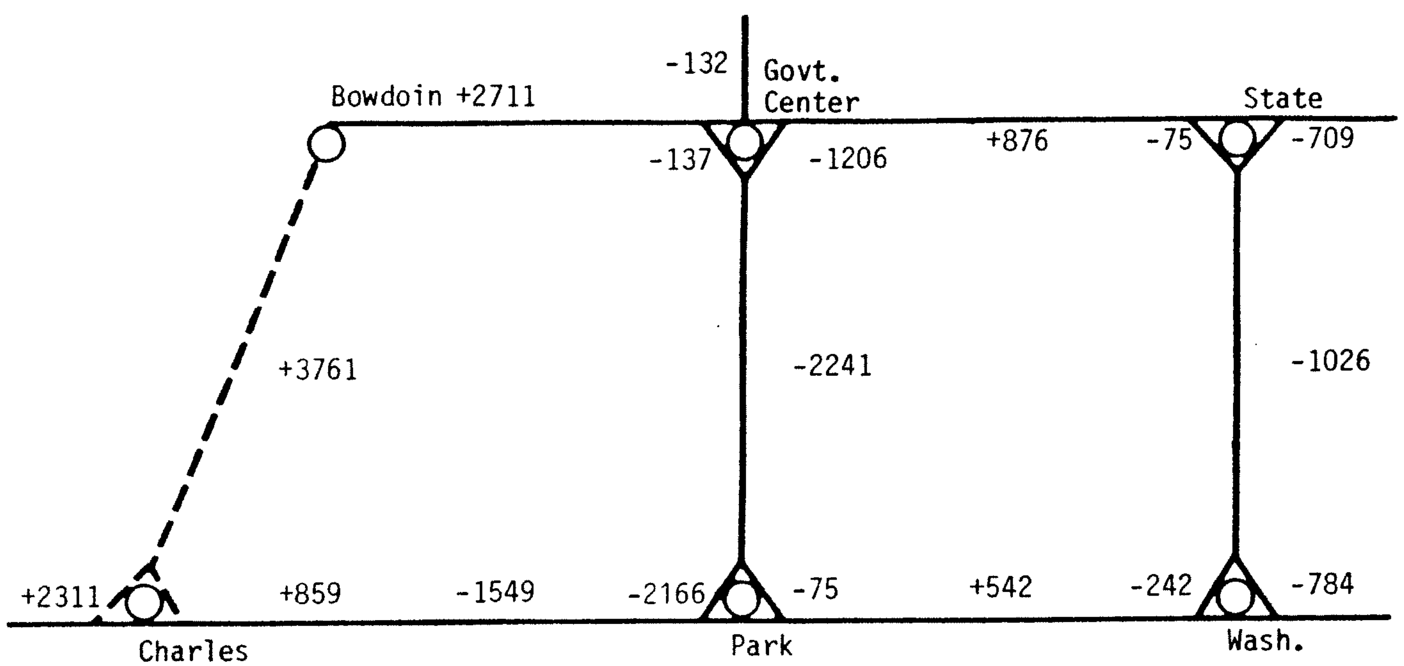


EXHIBIT 11

WEEKDAY ROUND TRIPS USING CONNECTOR
(Approximate Mid Point of Ranges)

BASE YEAR RIDERSHIP (No growth completed to allow direct comparison of scenarios)

	Pre THT Construction	During THT Construction	Post THT Construction
Logan Travel	900	1200	500
Red-Blue Corridors	1700	1900	1700
Downtown Diversion	1700	1900	1700
Total	4300	5000	3900
Approx. Annual O.W. Trips	2.5m	2.9m	2.2m

RIDERSHIP WITH PROJECTED GROWTH

	1990 (During THT Construction)	2010 (Post THT Construction)	2010 (Without THT)
Logan Travel	1400	950	1650
Red-Blue Corridors	1950	1900	1900
Downtown Diversion	1950	1850	1850
Total	5300	4700	5400
Approx. Annual O.W. Trips	3.0m	2.7m	3.1m

EXHIBIT 12

MODEL FORECASTS OF RIDERSHIP WITHOUT THT-CA
(Weekday Round Trips - 2010)

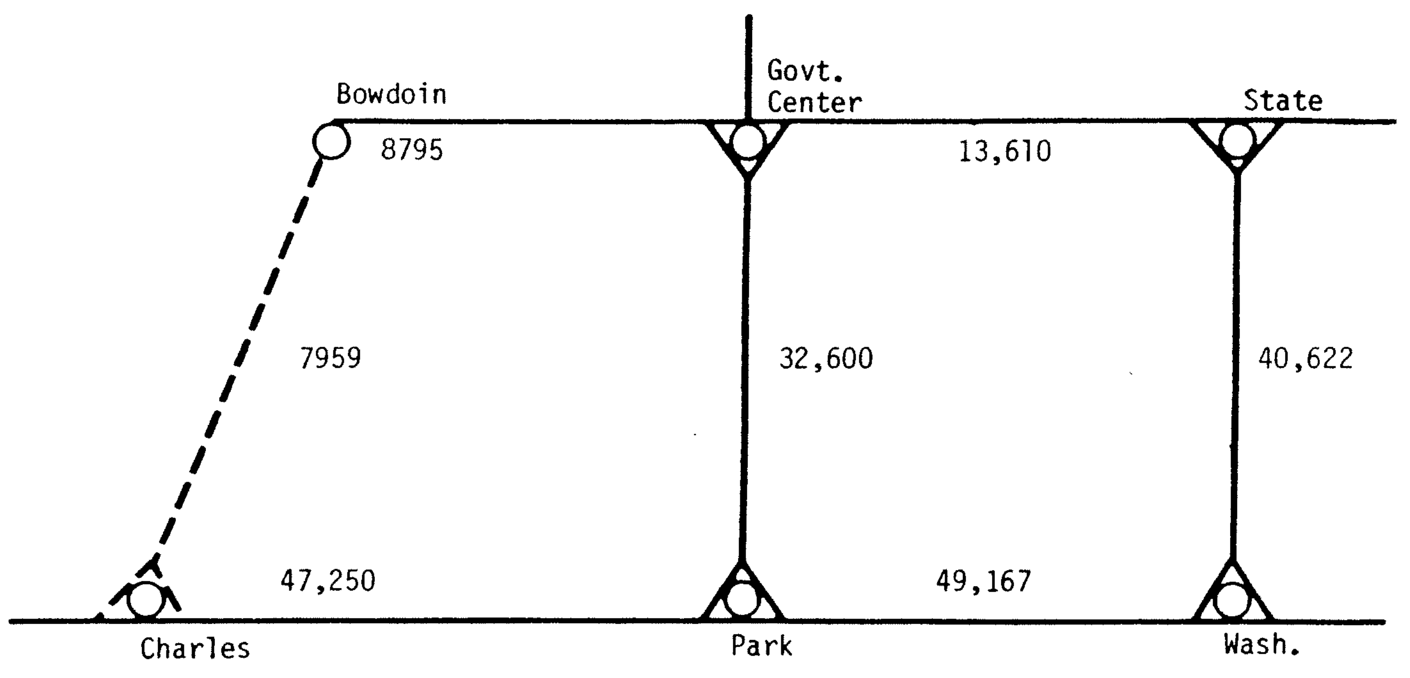


EXHIBIT 13

MODEL FORECASTS OF RIDERSHIP WITH THT-CA
(Weekday Round Trips - 2010)

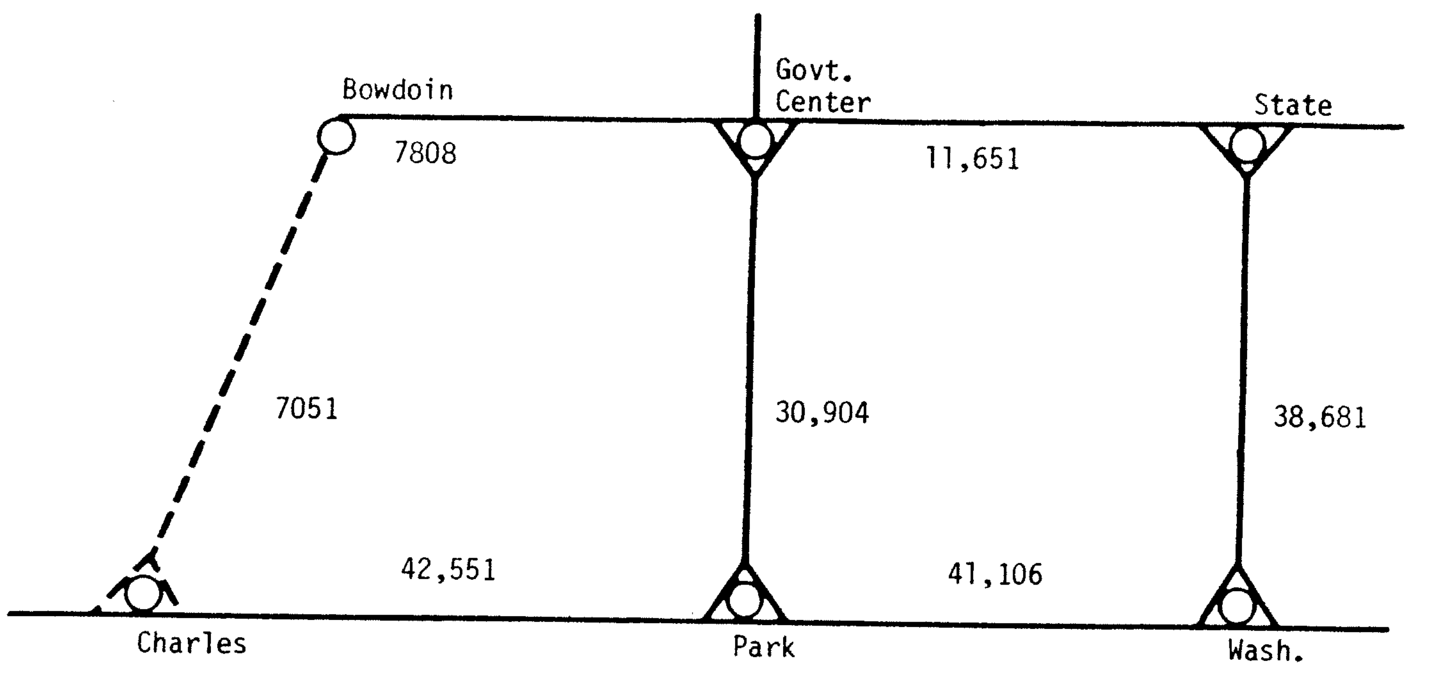


EXHIBIT 14

TRANSIT SYSTEM RIDERSHIP FORECAST
(Weekday - One Way Trips - 2010)

	Without THT-CA	With THT-CA
2010 Base Case Ridership	709,350	693,527
With Bowdoin/Charles Connector	711,957	695,845
Increase (Person-Trips)	2,607	2,318
Person-Hours Saved by Current Rides	608	538
Person-Hours Saved by New Riders	129	129
Transfers Saved by All Riders	7,483	6,447

III. TUNNEL CONSTRUCTION ALTERNATIVES

A. Existing Soil Stratigraphy and Water Level

Readily available information on soil and rock conditions along the project alignment indicate the presence of four distinct soil units and one rock unit below ground surface. Figures 1 and 2 indicate plan locations of available test boring information and a subsurface profile which illustrates soil and rock stratigraphy and groundwater levels. The subsurface profile was drawn based on available test boring information located within approximately 135 feet north and south of the centerline of Cambridge Street and Red Line and Blue Line alignments west of Charles Street Station and east of the portal at Joy Street, respectively. The legend, generalized description of strata and notes for subsurface information included on Figures 1 and 2 are included on Figure 3.

The stratigraphy along the alignment is generally comprised of the following subsurface units, listed in descending order below ground surface.

It should be noted that any one or more of the subsurface units listed may be absent at specific locations along the alignment.

- Miscellaneous Fill - A surficial stratum of miscellaneous fill blankets the entire alignment ranging in thickness from about 7 to 15 feet. The fill is characteristically variable in density with relatively high permeability.

- Tidal Marsh Deposits - Underlying the miscellaneous fill in some areas is a stratum of organic soil which may be up to 13 ft. in thickness.

  The original colonial shoreline traverses the site at about Anderson Street. The 1795 wharf line was located approximately 150 ft. west of the colonial shoreline at Cambridge Street according to available information. The 1850 wharf line was located in the vicinity of Charles Street Station.

  Based on the available subsurface information, the thickest organic deposits mainly occur west of Anderson Street near the limit of the old shoreline. Where organic deposits are present east of the old shoreline, this stratum is anticipated to be relatively thin (less than about 5 ft. thick). This stratum is generally highly compressible with relatively low permeability.

- Marine Deposits - Underlying the organic soils or miscellaneous fill (when organic soils are absent) is typically a 20 to 65 ft.-thick stratum of inorganic silty clay. The clay has overall low permeability. However, inter-bedded layers of cohesionless soil will be relatively permeable. The clay is thickest in the vicinity of Irving Street (65 ft.) gradually decreasing in thickness west of Irving Street (to about 40 ft. at West Cedar Street). East of Irving Street, the clay thickness decreases rather rapidly (to about 20 ft. at Joy Street.

  West of Charles Circle and east of Bowdoin Street is a marine deposit consisting primarily of granular soils overlain by tidal marsh deposits and underlain by inorganic silty clay. This layer consists primarily of medium dense to dense silty fine sand and gravel with interbedded clay and silt. This stratum may be up to 20 ft. thick west of Charles Circle to Storrow Drive and up to 40 ft. thick east of Bowdoin Street to Somerset Street.

- Glacial Till - Underlying the clay stratum is a stratum of glacial till. This stratum is present at depths of 35 to 80 feet below ground surface, being deepest near Irving Street and shallowest east of Irving Street at Joy Street. West of Irving Street, the top of glacial till is about 6 to 70 ft. below ground surface. Between the east and west project limits, glacial till was fully penetrated only in boring 852 (about 7 ft. thick). Other borings within the east-west project limits (nos. 853 and 854) penetrated into the till a maximum of about 7 ft. It is estimated that glacial till may be up to 30 ft. thick along most of the alignment.

- Bedrock - Bedrock typically underlies glacial till. At borings 854 and 855, however, rock was encountered directly beneath the silty clay at about 60 ft. depth. Bedrock was not encountered in any other borings between the east and west project limits. In general, the top of bedrock may be 75 to 100 ft. below ground surface west of Irving Street to Charles Circle and between a 50 to 90 ft. depth east of Irving Street to Joy Street.

Available information on groundwater levels in the project area consists of water levels measured in test borings at completion of the boreholes. This information indicates borehole waterlevels between 5 and 20 ft. below ground surface. West of South Russell Street, where the ground surface is relatively flat (El. 117) borehole water levels are at 13 to 20 ft. depth (El. 97 to El. 104). East of South Russell Street, where the ground surface rises (to El. 130 at Joy Street), water levels are about 5 to 13 ft. below ground surface (El. 113 to El. 120). In general, the available data indicate that the water level is at or slightly below the bottom of the fill.

It should be noted that water levels measured in test borings at completion of the borehole could have been affected by introduction of water into the boring during drilling, extraction of tools or other procedures and thus may not have reflected the actual groundwater level at the test boring locations. Near Charles Circle, groundwater levels are expected to be representative of the water level in the nearby Charles River (approximately El. 108, MDC datum). Proceeding east along the alignment, groundwater levels are expected to be near the top of tidal marsh deposits above the marine deposits.

Groundwater levels should be expected to vary with precipitation, season, leaking of nearby utility lines, water level in the Charles River, local construction activity and other factors.

B. Existing Utilities and Underground Structures

Numerous utilities and underground structures occupy Cambridge Street, as shown in Figures 5, 6 and 7. Most utilities (Water, Gas, Sewer, Electric and Telephone) run as two lines, with one service on each side of Cambridge Street. To the east of Joy Street, these utilities are located to either side of the existing Blue Line Tunnel. In addition, there is a major telephone duct bank which occupies the center of Cambridge Street to the east of Joy Street. The depth to which utilities occupy Cambridge Street varies from about 11 feet near Blossom Street to about 18 feet at Charles Circle. The existing utilities within the project limits are as follows:

Sewers:
- o 76" x 92" Boston Marginal Conduit and 36" x 54" West Side Interceptor, both crossing Charles Circle.
- o 36" x 51" Main Sewer along Cambridge Street.
- o 4 other storm and sanitary sewer lines (mainly 12" and 15" diam.) two on either side of Cambridge Street.

NET&T:
- o A major 80 duct telephone trunkline located in the middle of Cambridge Street. It contains NET&T telephone cables and AT&T fiberoptic cables. This duct bank was built in 1972 after many of the other utilities were already in place. It was located to avoid conflict with the other utilities and underground structures. Starting at Joy Street, it occupies the center of the street where there were street car tracks active until 1952. There is a major manhole located at the filled in portal area near Joy Street where these tracks originally came above ground from the Blue Line Tunnel. This and the other NET&T manholes are generally 15 feet deep. In the Charles Circle Area, the duct bank is believed to run under the existing 36"x 51" sewer at Charles Circle. The location will be verified upon further discussions with the telephone company.
- o 16-duct network on both sides of Cambridge Street.

Boston Edison: 16-duct Electric lines on either side of Cambridge Street with a tie-in at the former Boston Edison Substation near Charles Circle. Some of the Electric manholes are up to 18 feet deep.

Steam: 12" diameter steam line in a 3'-0" square concrete box located in Blossom Street and in Cambridge street to the east of Blossom Street.

Water: 16" diameter water line crossing Charles Circle. 2-12" diameter water lines on each side of Cambridge Street.

Gas: 2-12" Gas lines, one on each side of Cambridge Street.

Existing Underground Structures within the project limits are:

- o The existing Blue Line Tunnel.
- o Former portal and transition structure (retaining walls) used for grade level street car tracks which entered the Cambridge Street tunnel at Joy Street. This portal has been walled and the transition structure filled in and paved over.
- o Foundations of existing buildings along Cambridge Street.
- o Piles and pilecaps of the MBTA Red Line viaduct and the station structure housing the fare collection mezzanine.
- o Abandoned underground pedestrian passage crossing Charles Circle.
- o Other abandoned unknown structures such as old wharfs and foundations of buildings.

C. Tunnel Construction Requirements and Feasibility

1. General Description

The proposed Bowdoin Station-Charles Street Station Connector will have a top of rail profile approximately 27 to 37 ft. below existing ground surface. The relatively shallow depth of the transit structure eliminates, from a practical and economic view, the use of tunneling as a construction method.

Cut-and-cover construction is considered to be the most feasible construction method. Installation of braced temporary excavation support systems will be required to retain soil, ground water, streets, sidewalks and utilities. During wall system installation and excavation, obstructions may be encountered including: old buried wharf structures west of Anderson Street, all or portions of old trackage located down the center of Cambridge Street, granite blocks, wood piles, etc.

Building protection measures, such as underpinning or use of concrete diaphragm walls, may be required for structures located immediately adjacent to the proposed construction. It may also be necessary to maintain preconstruction water levels to prevent or minimize: a) consolidation of organic soils due to groundwater lowering and; b) potential damage (rotting) of untreated wood pile foundations supporting

adjacent structures, a problem which is well documented in Back Bay Boston.

2. Feasible Types of Temporary Excavation Support Systems

Three types of temporary excavation support systems are considered feasible for the proposed construction. They are: a) soldier pile and lagging wall; b) steel sheet pile wall, and; c) concrete diaphragm wall cast or constructed in a slurry trench.

Use of a soldier and pile and lagging wall would be appropriate where support of soil, utilities, streets and sidewalks are the only requirements of the support system. A soldier pile and lagging wall will not retain water. Nearby groundwater level will be lowered as excavation is conducted. Soil conditions are suitable for installation of soldier piles by driving. However, noise from pile driving in the vicinity of Massachusetts General Hospital may be an important consideration. Soldier piles can be installed in predrilled holes without driving if noise considerations dictate.

If it is necessary to maintain groundwater at preconstruction levels due to concerns mentioned previously, a steel sheet pile wall could be used. In addition to offering excavation support similar to a soldier pile and lagging wall, a properly installed steel sheet pile wall can also retain water. Based on the soil conditions at the site, it is anticipated that sheet piling can be driven without much difficulty. It may be necessary to pretrench through the fill to remove obstructions to sheet pile installation. Noise from sheet pile driving may be an important consideration as well.

Neither soldier pile or sheet pile walls are considered stiff or rigid enough to offer adequate protection of buildings located adjacent to the sheeting line. Adjacent structures with foundations bearing within the zone of influence* of an excavation supported by soldier pile or sheet pile walls may require underpining. Alternative methods of underpinning are discussed in a subsequent section of this report.

Structure underpinning can generally be eliminated through use of concrete diaphragm walls cast or constructed in a slurry trench (slurry walls). This type of support system is advantageous in that it has greater rigidity than soldier pile and sheet pile walls. Concrete diaphragm walls have demonstrated performance in building protection equal to or exceeding that provided by underpinning. In addition, this type of wall will retain groundwater similar to a sheet pile wall and can sometimes also serve as the permanent transit structure if design criteria permits. Architectural cavity walls may be required in public occupied space due to the rough and irregular appearance of a concrete diaphragm wall and since diaphragm walls generally leak and weep resulting in an unattractive appearance.

In terms of relative cost, a soldier pile wall with cast-in-place transit structure walls will probably be the least costly alternative followed by a steel sheet pile wall with cast-in-place transit structure walls. The concrete diaphragm wall alternative will probably be most expensive. If extensive underpining of adjacent structures is required in conjunction with soldier pile or sheet pile walls, it may be more economical to use a concrete diaphragm wall in these areas.

3. Bracing Systems and Decking

Excavation depths from approximately 30 to greater than 40 ft. will be required for construction of the proposed transit connector. Temporary excavation support systems will, therefore, require bracing. At least one level of bracing is anticipated for excavation depths up to 25 to 30 feet. Excavation depths in excess of 30 feet will probably require a minimum of two levels of bracing.

The soil conditions along the project alignment are considered suitable for use of external bracing by tiebacks. Tiebacks can probably be anchored either in the surficial fill or in the underlying marine deposits. Installation of tiebacks in organic silt should be avoided to the extent possible because of its low strength and related poor tieback performance. Presence of utilities, foundations of adjacent structures and other below grade structures and easement restrictions may limit use of tiebacks at some locations.

Alternatively, internal bracing in the form of prestressed cross-lot struts and corner bracing can be used to restrain support system walls.

* The zone of influence is defined herein as the area adjacent to the supported excavation within which soil movements associated with excavation might be expected to be of a sufficient magnitude to warrant some positive form of protection for buildings with foundations bearing within the zone. For this feasibility study, in consideration of the present deficiency in building foundation information and site specific subsurface information, buildings adjacent to the alignment with plan locations within a 1 horizontal to 1.5 vertical line drawn upward and outward into the retained soil from the bottom of the excavation at the exterior of the support system wall are considered to be within the zone of influence of the excavation.

For either type of bracing system, it is important to install the bracing, particularly the top level, in a timely manner to restrain the wall before excessive wall system movement can occur.

Since excavation will be conducted within a main thoroughfare, it is anticipated that a modular traffic deck panel system over the excavation will be required. Traffic maintenance criteria for the project will dictate the extent of decking and underdeck construction work.

4. Dewatering

The proposed construction will require an excavation which may be 10 to 20 feet below prevailing groundwater levels. As discussed, the stratigraphy consists primarily of granular, relatively permeable fill underlain by cohesive, relatively impermeable organic silt and/or inorganic silty clay. In general, preconstruction groundwater levels are expected to be near the bottom of the fill.

Dewatering requirements will be greatest if a soldier pile and lagging wall is used because of the previous discussed nature of the wall. Due to the presence of relatively impervious soils below the groundwater level, it is likely that dewatering can be effectively accomplished through pumping from sumps in the excavation. There will probably be isolated zones or layers of permeable soils (sand and gravel) interbedded in the clay, as discussed previously, which may yield water. The majority of water may originate from the fill/organic soil or fill/silty clay interface.

If sheet pile or concrete diaphragm walls are used, dewatering requirements will be less, probably consisting of intermittent sump pumping from within the excavation.

5. Utility Support and Relocation Methods

The relocation of utilities within the alignment right-of-way and intersecting the alignment will be extensive and will require careful phasing so that the construction schedule is not adversely impacted. The utilities within the limits of excavation that run parallel to the alignment will probably have to be relocated to the side of the proposed right-of-way during construction and possibly relocated back to their original locations after the transit structure has been completed. Alternatively, utilities may be permanently relocated or in some instances temporarily supported in-place within the right-of-way.

The utilities that intersect the alignment at the cross streets may have the greatest impact on construction scheduling for cut-and-cover construction. One procedure to handle the intersecting utilities is to have several utility corridors at the street intersections. During the construction, several utilities would be brought together and temporarily supported across the alignment within the utility corridor. Support of the utilities could also be accomplished by hanging them from the temporary deck, supporting them on the walls of the excavation support system or providing individual temporary support with piles.

6. Protection of Adjacent Structures

Excavation required for construction of the cut-and-cover transit structure will result in ground movements and/or strains that translate into vertical and horizontal movement of the ground adjacent to the excavations. The ground movement may have potential impact on adjacent structures (buildings and utilities) to the point that some form of protection may be required to ensure continued integrity of adjacent structures. The magnitude of expected ground movements adjacent to excavations depends on several factors. The major factors are expected to be loss of ground into the excavations, stiffness of the excavation support system, method of wall installation, and timing of the bracing installation.

As mentioned above, the use of a concrete diaphragm wall will provide the required temporary excavation support and, because of its rigidity, should provide adequate building protection to preclude direct underpinning of adjacent structures. Adjacent structures located within the zone of influence of an excavation supported by soldier pile and lagging and sheet pile walls may require underpinning. Underpinning consists of lowering the support level of existing structure foundation elements to a suitable bearing level below the zone of influence of the cut-and-cover excavation for the new structure or alternatively maintaining support of the structure by jacking to recover movements. The purpose of the underpinning is to minimize movements of structures which occur as a result of excavation-related ground movements.

It should be noted that inherent in the underpinning process is settlement of the structure during underpinning resulting from transfer of load from existing to underpinning foundations. Properly conducted underpinning can usually limit structure settlement to 1/2 inch or less. Feasible underpinning methods include pit underpinning, bracket pile underpinning, root piles and maintenance underpinning.

Three to five piers supporting the Red Line will be affected by the construction required for the station alternates proposed in this report.

Some of these piers will be located within the limits of the proposed construction. Temporary support of these piers will

be required to allow new station construction and new pier support. Temporary support could be provided by end bearing piles installed to the level of glacial till. Loads from the existing structure could be transmitted to the piles by underpinning with temporary transfer beams and other structural connections during construction. Temporary support would be removed when the permanent support is constructed and is in place.

A different approach would be required for piers located immediately outside (5 to 10 ft.) the limits of the proposed station construction. Available drawings of Charles Street Station indicate that the piers are supported by untreated wood piles. It is likely that the piles fully penetrate miscellaneous fill and organic soil layers and bear in the underlying marine deposit. It is estimated that the piles may penetrate a minimum of 10 to 15 feet into the marine deposit assuming 10 ton design capacity and conservative pile/soil adhesion values. This would place the tips of the piles supporting these two piers in the range of about 35 to 40 ft. below ground surface.

Excavation depths in this area may be 39 to 41 ft. assuming top of rail at 36 ft. depth. Therefore, excavation might be conducted to or slightly below the tips of the piles supporting the piers.

At this time, it is anticipated that direct underpinning of these piers will not be required. However, maintenance underpinning may be appropriate. Observations of the pier structure indicate that the steel box structure which contains tracks and ballast rests on a steel beam connected to the pier. No significant connection of the steel box structure to the steel beam was observed. It appears that jacking seats could be attached to the steel beam and the steel box structure jacked and shimmed as required if the pier should settle as a result of construction.

Regarding protection of other structures along the transit alignment, projection of the zone of influence line to ground surface around the limits of proposed construction indicates that many existing structures along the alignment will be within the zone of influence and, thus, may require some form of building protection.

The selection of the most feasible and economic scheme of protection must take into account many factors. These include construction procedure, structure type, estimated magnitude of movement, and subsurface conditions. The most applicable system is, typically one in which the most flexibility can be maintained. If the protection is conducted in conjunction with a monitoring program, modifications during construction can be implemented as required. This approach will usually result in an economic system of protection.

It should be noted that in some instances, protection of a structure may involve a cost greater than the structure itself. In these instances, consideration should be given to the purchase of the structure, the purchase of special insurance policy to cover repair to the structure or the negotiation of an agreement with the property owner to limit the liability of the transit authority should damage occur as a result of construction.

7. Staging and Traffic Diversion Considerations

From visual observation of Cambridge Street during the rush hour it is apparent that there is a substantial need for storage space for an inventory of cars due to congestion in the Charles Circle Area. It is assumed that in the construction area there is a need for inventory space in addition to lanes for moving traffic. An acceptable rate of movement may be achieved by closing some of the existing six lanes for a short length of Cambridge Street to allow cut-and-cover construction, while keeping the remainder of the street for inventory. It appears that two lanes of traffic will be needed in each direction on Cambridge Street. This street is generally 82 feet wide, which will allow for 38 feet for construction purposes in addition to four 11 foot wide temporary lanes. The construction could progress by excavating and supporting construction in a small area, say several hundred feet in length, at a time. A modular concrete decking system supported on steel beams would then be installed. Construction could take place under the decking and the decked over areas be used for traffic. Once this decking is in place, open cut construction can continue in the next section. By proceeding in this sequence only a portion of Cambridge Street would be unavailable for traffic at any time. The prefabricated modular decking panels will allow for the placing and replacing of panels depending on the phasing sequence required for the underground excavation, construction and traffic diversion.

In the Charles Circle area there will be extensive excavation for rerouting of utilities, underpinning of structures and construction of the new station. This area of excavation will affect nearly all of the twenty-one intersection turning movements identified in DPW traffic counts for Charles Circle. The existing automobile counts show relatively light traffic volumes. It appears that the intersection turning movements can take place with fewer lanes, provided there is sufficient inventory space and temporary signalization. Where these fewer lanes are possible, open construction can take place in a portion of the roadway, then be decked once to allow construction in the remaining area.

The available traffic counts for Charles Circle are for cars only and do not include truck volumes or identify data on the effect of the existing traffic signalization. A complete capacity analysis of the entire intersection and of Cambridge Street will be required in a later phase of the construction project in order to complete a staging plan in this area.

8. Proposed Structural Alternatives

The cut-and cover method of construction is the most feasible method due to the shallow depth required for the subway extension. Design of the underground structures will be influenced by the alignment required for the new subway, the geological conditions, utility protection requirements for nearby structures and required surcharge loads and hydrostatic pressure. In the review of these characteristics and the proposed site, it appears that these features can be grouped into three distinct zones within the project area.

The first of these zones is the area around Charles Circle. This area has a high water table relative to the depth of excavation. Existing structures close to the area needed for construction of subway structural walls precludes the use of a soldier pile and lagging excavation support. There is insufficient width for soldier pile and lagging which requires approximately 4-5 feet from the face of the excavation support to the face of the outside of the tunnel wall construction required for soldier pile and lagging. The proximity of building foundations and other structural foundations in the area tends to favor a rigid type of excavation support such as a slurry wall. The slurry wall has an added advantage of being relatively impervious to water infiltration compared to some of the other excavation support systems.

The second zone in the project area is east of the station area where the tunnel contains 2-4 tracks depending on the tunnel configuration for each of the proposed schemes. The tunnel in this area is generally wider than it is at the eastern limit of the project area near Bowdoin Station. This area is characterized by a tunnel alignment which is generally closer to the northern side of the street than the southern side of the street. The northern side of the street has very few structures near the curb line which is the northern most extent of tunnel structure alternatives proposed in this report. To the south of the tunnel structure in this area, there are several older buildings mostly four stories in height. The distance between these buildings and the tunnel does not place them within the zone of influence where the soil movements associated with the excavation might be expected to affect their foundations. The soil stratigraphy in this area indicates that the excavation will be mostly in Boston blue clay. The relatively impervious blue clay will limit the amount of water entering the excavation area. In this zone, there is sufficient room to allow use of solder pile and lagging system for support of excavation which is a less expensive system than the slurry wall method. For these reasons, the soldier pile and lagging excavation support method is recommended in this section.

The tunnel construction for zones 1 and 2 could utilize a rigid cast-in-place U-box configuration with a steel strut supported concrete roof. The U-box would be designed to resist side sway conditions where future excavations may subject the tunnel to a full soil load from one side. The use of the steel and concrete roof structure will also provide ease of material movement and construction work in the space underneath the traffic decking. An alternative to this construction method would be to provide a concrete cellular box construction where the roof and interior and exterior walls and floor all counteract the side sway conditions described above and the soil pressure on all sides of the box. Depending on the track configuration, there could be one to four box cells. One cell could be used where there are two tracks and three to four cells could be used at multi-track areas of the subway tunnel. The intermediate walls between cells would be omitted at locations for diamond cross-overs and turn-outs. Figure 14 shows the proposed construction method for the cut-and-cover construction with the traffic decking and utilities supported in place. The U-box and the cellular box construction methods are shown in the typical sections in Figure 15. The U-box is shown in the sections typical for Station 13+00 to 22+80 and the cellular box is shown in the section typical for Stations 10+00 to 13+00. The two methods have been shown in the typical sections for the purpose of illustrating the two alternatives. Final design will most likely proceed using one method.

In both Zones 1 and 2 there will be a requirement of either relocating or supporting in place the many utilities in Cambridge Street. There is sufficient space between the proposed roof of the subway tunnel and grade to hang the utilities in place from the proposed traffic deck structure. With the traffic deck in place there is also sufficient space below the deck to conduct excavation and construction of the floors, walls and roof of the subway tunnel.

The third zone is the area of the existing Blue Line tunnel west of Bowdoin Station which requires reconstruction in order to lower the vertical alignment. In the third zone there is less distance from the street level to the subway roof. In this area there are many utilities above the tunnel structure or quite close to the walls of the existing Blue line tunnel. For these reasons it may be more feasible to leave the existing tunnel walls and roof in place. The reconstruction of the lower portion of the tunnel can be

accomplished by underpinning the tunnel walls and excavating down to the level required for the subway tunnel. The geological data indicates that there is glacial till in the excavation area which will provide a good level of bearing capacity for underpinning of the subway tunnels in this area.

9. Trackwork

Concrete ties and ballast is proposed for the trackwork in the station and tunnel. This will allow maintenance practices consistent with the rest of the Blue Line. Turnouts and diamond crossovers are provided within the track area to the east of the station. In order to provide a comfortable ride and maximum design velocity, the maximum possible radii of track will be provided. Number 8 turnouts or larger are recommended for revenue tracks and Number 6 for storage tracks. All trackwork will meet MBTA standards.

10. Signals

The signal and communications system will employ modern automatic wayside colorlight signals for double-direction train operation on both tracks. The signals will be spaced for maximum safety and stopping distance and will provide minimum operating headway required for train operation of the Blue Line. The signal design and equipment will be compatible with the existing signal system. As automatic train control (ATO) is planned for the Blue Line in decade after this tunnel is constructed, provisions should be made for its future installation. An automatic interlocking will be provided for safe and efficient train movements to and from the turnback and storage tracks, located east of the station. The automatic routing will provide first-in, first-out operation. A supervisory control and indication panel will be located either in the High Street Control Center or in East Boston. It will allow manual control of the maintrack interlocking and switches for the run as directed (RAD) train storage tracks. All track circuit occupancy indications within the project limits will be transmitted to the Control Center and displayed on the train dispatcher's indication panel board to inform the dispatchers of train operations within this area.

11. Plumbing and Fire Protection

Plumbing will be required for public toilets and station maintenance. Fire protection will include a dry stand pipe system for the new station and tunnel extension. Roof drainage will be required for above ground structures. The sidewalk ventilation grates will require a drainage trough system. In the track area there will be a drainage system to collect seepage and any storm drainage runoff which might enter the tunnel. Since the new tunnel invert is below nearby drain lines , a drainage pit and duplex sump pump will be required.

12. Ventilation

A ventilation chamber is required for the new tunnel extension. The ventilation chamber should be sized for non-mechanical ventilation due to the piston effect of train movements and requirements for ventilation fans which would be part of the fire protection system. The ventilation chamber should be located between the station and tunnel to alleviate uncomfortable drafts caused by trains entering and leaving the station. Sidewalk ventilation grates would be located over the shafts shown in the plans proposed schemes.

13. Traction Power

The third rail in the Blue Line extension will be sectionalized into two parts, the northerly (westbound) and the southerly (eastbound) track. Each section will require two sources of power. Feeders would most likely be from the North Station Haverhill Street Substation and Kendall Substation. A power demand analysis is required to determine feeder sizes and to verify that substation capacity is available. Further investigation will be required to determine if space is available in the Causeway Street duct bank from the Haverhill Street Substation. Cable from the Kendall Substation would cross the Longfellow Bridge.

14. A.C. Power and Lighting

A new 480V 3 phase electrical service will be required from Boston Edison Company to serve the existing Red Line Station and the new Blue Line Station, as the existing 120V station service will be insufficient for the increased loads. Major power loads include elevators and escalators, ventilation fans, drainage pumps, lighting and miscellaneous uses such as heating for token booths.

All areas will have a percentage of lighting fixtures on an emergency power system.

15. Communications

Communication systems will include a public address system, fire alarm system and a closed circuit television system for security surveillance. Consideration should be given to providing train indication panels to inform transferring passengers. Pump and fan controls and indications for the Systemwide Supervisory Control System should be considered. The existing telephone system will be extended to include the MBTA and public telephones.

D. Tunnel Design Alternatives

1. Alignment Considerations

a. Horizontal Alignment
The required tie-in at the existing portal near Joy Street determines the horizontal alignment at the east end of the tunnel extension. At the new station, at the west end of the extension, the vertical circulation elements, stairs, elevators and escalators must be aligned to connect with the Red Line platforms above. In addition to these end points, the horizontal position of station and tunnel is influenced externally by the proximity of utilities and underground structures. Internally the tunnel must conform to a viable track configuration. Between Grove and Blossom Streets, the tunnel walls will run parallel with Cambridge Street and will be centered on the existing tunnel in order to minimize utility relocation. Shifting the bulk of the wider portions of the tunnel to the northerly side of Cambridge Street will also minimize underpinning of the buildings at the south side of Cambridge Street. The location of the piers supporting the Red Line viaduct which curves to the south also favors placing the Blue Line extension to the northerly side of Cambridge Street. The major sewer line under Cambridge Street runs diagonally from the south side of the existing Blue Line tunnel to the north side of the street at the western portion of the project site. The tunnel alignment should be on the north side of the street to allow reconstruction of the sewer to the south of the tunnel.

b. Vertical Alignment
Generally with cut and cover construction, the vertical alignment should be close to the surface to minimize excavation and support costs. In the project area Cambridge Street crests at Bowdoin Street and then slopes downward at approximately 4 1/2% to about Russell Street (towards the Charles River). Between Russell Street and Charles Street the slope is relatively level. There is a 10 foot difference between the street elevation above the end of the existing tunnel and at Charles Circle. At the eastern portion of the project site the vertical alignment must tie in with the top of rail of the tracks in the existing Blue Line stub tunnel near Bowdoin. In order to minimize the vertical travel distance for passengers transferring from the Red Line to the Blue Line, the vertical alignment at Charles Circle should be at the minimum depth to clear utilities or keep their relocation to a minimum. In the center of the alignment the tunnel slope is governed by the 4 1/2 percent slope of Cambridge Street and utility locations. Minimum cover of the subway box of approximately 11 feet near Blossom Street and 15 feet at Charles Circle is sufficient to avoid a costly relocation of the telephone 80-duct bank.

2. Operational Feasibility

The Blue Line runs on a four to five minute headway during peak periods. Future operations could be at a three minute headway. Travel time between the existing Bowdoin Station and the New Charles Station will be approximately one minute. The new station will be a stub end terminal, which will require the motormen to change his position from one end of the train to the other for the return trip. This will take a minimum of three minutes, and most likely for scheduling purposes, four minutes should be allowed for the change from one end of the train to the other. With a turnaround time equal to or greater than the headway, a minimum of two tracks will be required for peak period operation.

Another operating requirement for a terminal station at Charles Street would be for providing space for "run as directed" (RAD) trains. The RAD trains would be put into service when the frequency of train service is increased or when a substitute is needed for a train that is put out of service. Since the only yard space for Blue Line trains is at Orient Heights and Wonderland, there is a need for a storage facility at the Westerly end of the Blue Line System. Currently there is storage for two RAD trains in the existing pocket to the west of Bowdoin Station. At least two train locations for RADs should be also provided in the proposed Blue Line extension.

3. Track Design Alternatives

During the course of this study several combinations of storage tracks and revenue tracks have been evaluated. These are shown as schematic track diagrams in Exhibit 15 and are described below:

Scheme 1: Includes two passenger platforms in the Station serving three tracks. These tracks would be used alternately for either run as directed trains or revenue trains. During off-peak periods, when headways are six minutes or longer, only one track will be required for turnaround of revenue trains. The two train storage requirement for RAD's is also off-peak. Thus, with this scheme the two revenue trains in peak period and the two RAD's during off-peak can be accommodated by this three track scheme. The track configuration east of the platforms includes two equilateral turnouts connecting the three station tracks to the two tunnel tracks. East of this location there is a diamond crossover. From the operations point of view, Scheme 1 has a good degree of flexibility in allowing trains coming from the east to use any of the three station tracks. A two platform configuration could be a disadvantage from the passengers point of view in some situations. For example, if passengers

are waiting for a train on one platform and then find out the next outgoing train can only be reached from the other platform, they would have to walk from one platform to another to board a train.

Scheme 2: This scheme has a single center platform with a track on either side. The tunnel to the east of the station in this scheme has three tracks. Two of these tracks will be used for eastbound and westbound moves and the third track would be used for storage of two RAD trains. This scheme also has a diamond crossover between the east and westbound tracks which allows an eastbound train to make a move to either side of the platform. The northerly track in the tunnel is the run as directed track and it serves only the northern track in the station. A single center platform serving the two operating tracks, a diamond crossover and space in the tunnel for two run as directed trains is the advantage of this scheme. The drawback to this scheme is that only the northerly track in the station can directly receive the RAD trains which are stored in the tunnel.

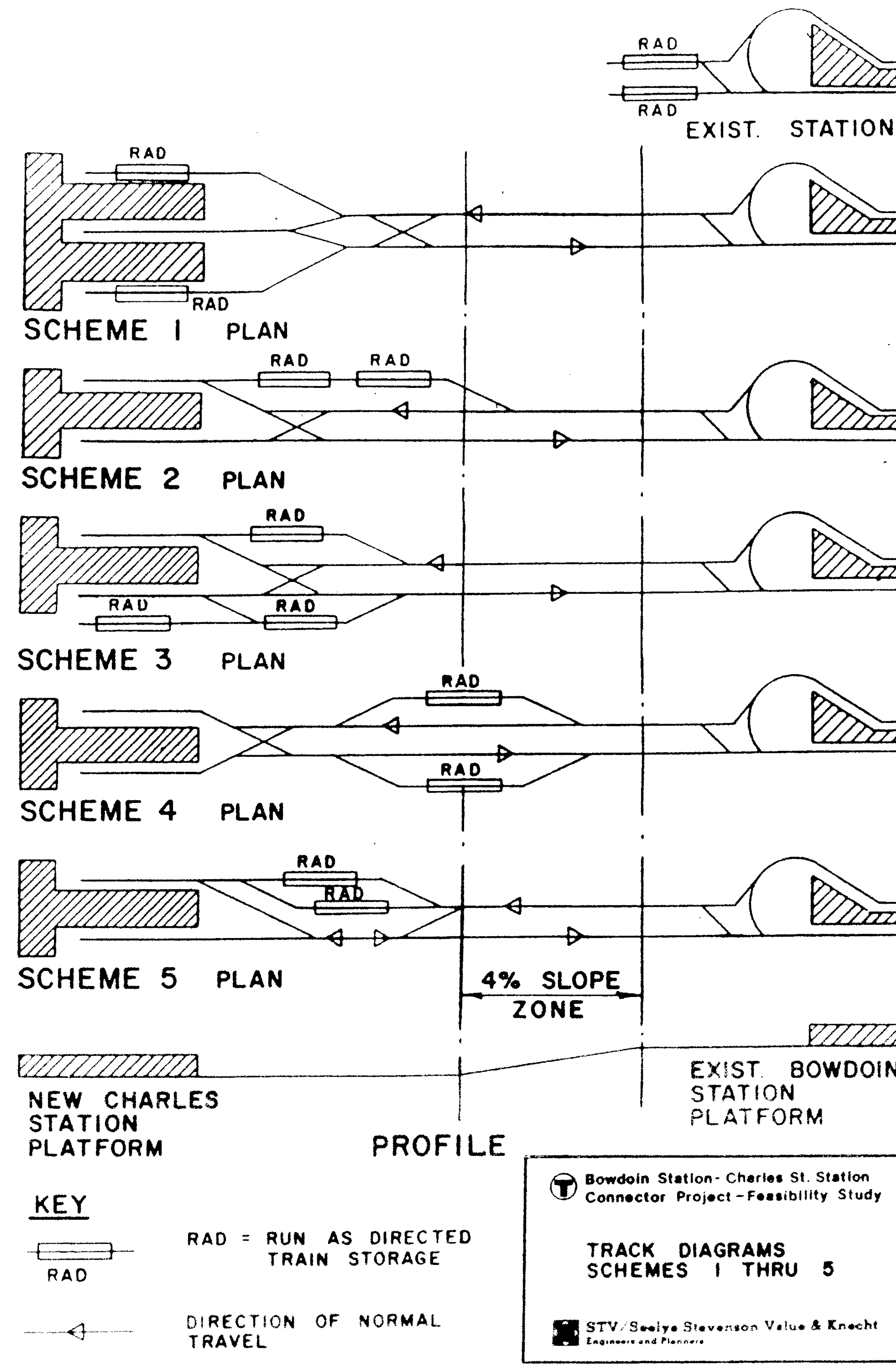
Scheme 3: This scheme is similar to Scheme 2 as there is a single center platform serving two revenue tracks, storage for two RAD trains in the tunnel and an additional third RAD track, south of the southerly platform track and a diamond crossover between the east and westbound tracks. This scheme has a four track configuration in the tunnel which provides the added flexibility of two run as directed train storage tracks, each serving a side of the platform.

Several other track configurations were evaluated and were found to be less desirable. Two of these are identified as Schemes 4 and 5 in Exhibit 15.

Scheme 4: This four track scheme has a diamond crossover between the two platform tracks and the tunnel tracks which include two RAD storage tracks and two running tracks. The diamond crossover allows all four tunnel tracks to serve either platform track. There is approximately 700 feet between the end of the station platform and where the tunnel track rises at 4% towards the existing Blue Line tunnel. The length of the track work required for this scheme would place the stored trains in an undesirable location on the 4% slope. This scheme will be relatively more expensive to construct as the tunnel area would be larger than the other schemes.

Scheme 5: This three track scheme has two storage tracks, each with sufficient space for holding one RAD train. The third track would be used for both eastbound and westbound trains. This single track operation makes this scheme less desirable than the three track configuration in Scheme 2.

EXHIBIT 15



Bowdoin Station- Charles St. Station Connector Project - Feasibility Study

TRACK DIAGRAMS
SCHEMES 1 THRU 5

STV/Seelye Stevenson Value & Knecht
Engineers and Planners

IV. STATION ALTERNATIVES

A. Design Goals

1. Urban Context

The study area contains a wide range of land uses including residential, institutional, commercial and recreational. Cambridge Street is the major traffic artery and the connecting link between Charles Station and Bowdoin Station. Together with the historic Longfellow Bridge, it creates a direct visual link between Cambridge and downtown Boston/Government Center. The northern edge of the street contains the high-rise, institutional and commercial area of the West End, including the Massachusetts General Hospital and also the landmark Charles Street Jail. The southern side encompasses the low-rise, residential district of Beacon Hill. Charles Circle, at the base of Cambridge Street is one the symbolic gateways to downtown and the place where all of the diverse land uses merge.

The existing Charles Station viaduct creates a long, linear visual barrier across Charles Circle on an east/west axis. Today, the station headhouse is isolated on one of a series of small islands, surrounded by a complex traffic intersection. Originally the headhouse was conceived as a comparatively small vertical element, located in the center of a large landscaped circular island which formed a well defined traffic intersection. Pedestrian access was at grade, along a series of walkways that radiated symmetrically from the headhouse out to the edge of the intersection. Now a system of overhead walkways which span the multiple traffic lanes provide the only pedestrian access to the station. These walkways contribute to an overall effect of visual disorder.

Urban design criteria must be developed to address the problems of vehicle and pedestrian circulation and visual chaos. Specific urban design goals of this project are:

a. Improve vehicle circulation within Charles Circle by means of selective street realignment, improved signalization and redesign of the traffic islands around the station headhouse.

b. Improve pedestrian circulation by eliminating the system of overhead walkways and replacing them with more direct attractive and secure underground passageways to connect the street level with a new Charles Street lobby and also provide a direct passage between the north and south sides of Charles Circle. Visual clarity will be improved by elimination of the overhead walkways.

c. Develop street level amenities through careful locations and design of station entrances. Design should respond to neighboring structures and to proposed Charles Circle pedestrian and vehicular circulation improvements as well as provide the most direct route to the station lobby.

d. Develop the above ground station elements to create a formal and recognizable termination for the end of Charles Street and a visual focus for Cambridge Street.

e. Utilize station design to enhance Charles Circle as a visual object. Reestablish the concept of the station itself as an integral element within the Circle instead of being perceived as the underside of a viaduct.

f. Station architecture should acknowledge the historical context of the Charles Street Jail, Beacon Hill and the Longfellow Bridge.

2. Impact on Transit Users

Street level station entrances should be located on the north and south sides of Charles Circle. A single entrance should be provided on each side of the circle in order to simplify visual identification and to promote greater patron safety. Entrance location should permit the shortest pedestrian travel distance from the street level to the fare control zone.

A single fare collection area should serve both the Red and Blue Lines. The optimum location for fare collection would be midway between the Red and Blue Line platforms. It should be situated close to the station entrance passageways.

Passenger transfer between the Red and Blue Line platform levels should be as direct and convenient as possible. Horizontal travel distance between the middle of both platform levels should be kept as short as possible. Careful placement and design of the vertical circulation components can help to reduce the actual and perceived travel distance.

The use of escalators as a primary circulation element is mandatory due to the large vertical distance between the two platform levels. Two escalators, one operating in each direction is required to serve each platform. Since the existing Charles Station has side loading platforms, a total of four escalators should be provided. In addition to escalators, each platform needs to be served by a stairway and an elevator. Elevators must serve not only handicapped patrons but also airport bound passengers with luggage. Station entrances should contain a stairway and a single escalator equipped for reversible operation. Handicap access from street level would require a minimum of one elevator,

preferably at the north entrance which would serve Massachusetts General Hospital. Provision for an additional elevator at the south entrance should be studied.

Patron security and station surveillance should be a primary consideration in development of design alternatives. Station layouts should allow for maximum visual surveillance from the fare collector's booth. Passageways from street entrances should be observable from the station lobby. Details of railings or low partitions at landings and around escalators and stairs should permit visual observation from platform and lobby levels. Elevator cab enclosures and elevator shaftways should include transparent elements that allow observation from lobby and station areas. The installation of a closed circuit TV system monitored by the MBTA should be considered as an additional security measure.

Station finishes, both interior and exterior must conform to the MBTA Guidelines for approved materials. Approval criteria for finishes include safety (fire, smoke, etc.), durability, ease of maintenance, aesthetic effect and economy. Exterior finishes should also be compatible with adjacent structures in Charles Circle and with the existing Charles Station construction.

3. Building Space Program

a. Lobby Area

1. Unpaid Circulation Space
This is part of the station entry passageway. It should have visual surveillance from the fare collection booth. Graphics, telephones, etc. could be incorporated in this space but should not inhibit patron circulation. Size of the space will vary according to patronage and station entry layout.

2. Fare Collection
The function of this area is to control subway entry and exit of fare paying passengers. The booth attendant also provides information and station surveillance. Components include two fare collection booths, a number of automatic turnstyles (final number of turnstyles is dependent on patronage requirements), a pass gate and emergency gates.

3. Paid Circulation Space
This circulation space connects the fare collection area with vertical circulation elements. Queue space for exit fare collection should be provided to allow future revision of fare structure by the MBTA. Public and employee support spaces should be located adjacent to this area.

4. Public Toilets
Sanitary facilities for MBTA patrons, including handicapped persons should be provided. One men's and one women's toilet room is required. These facilities are to be adjacent to the paid circulation area and should be visible from the fare collector's booth. A minimum of 100 square feet is required.

5. Employee Toilets
One men's and one women's toilet room should be provided for station personnel. They should be located near the paid area and be visible from the fare collector's booth. The minimum size for each toilet room is 25 square feet.

6. Safe Room
A room containing 75 to 100 square feet for cash deposits and temporary storage of fare boxes should be located convenient to the fare collection area with access from the paid area. Visibility from the fare collector's booth is desirable.

7. Lamp Storage Room
At least 100 square feet of space should be provided for lighting fixture and lamp storage. The space may be adjacent to the station electric room, but with a separate entrance.

b. Platform Area

1. Passenger Platform Area
Passenger platforms should have direct access to and from vertical circulation, provide views of oncoming trains and have provisions for emergency egress. Platform components should include benches, graphics, system information and trash receptacles. Platform length should accommodate 6 car trains with sufficient width to accommodate the circulation of waiting, embarking and disembarking passengers.

2. Train Starter's Room (Blue Line Only)
An area of 25 square feet visually aligned with the center of the platform should be provided for a train starter's work station. This room is usually a prefabricated component.

3. Third Rail Disconnect
A cabinet, 4 feet wide by 2 feet deep by seven feet high which contains the third rail power disconnect switch, should be easily accessible to the motorman of a train on each track. The cabinet could be

located on or just beyond the edge of the platform at the train departing end.

4. Communications Equipment Room
A room containing equipment for the P.A. system, train radio system, fire detection alarm system, etc. should be provided at the lobby end of the platform level. A minimum of 150 square feet is required plus additional space for future systems.

5. Signal Equipment Room
This room should be located adjacent to the communications room. It contains line signal equipment. Conduits and ducts from this room must be routed to the train tracks. Size of the space to be determined by the MBTA requirements.

6. Elevator Equipment Room
A space approximately 8 feet by 9 feet with a minimum 7 foot 6 inch headroom and a four foot wide door should be located at the platform or lowest level adjacent to or within ten feet of the elevator shaft. The room houses hydraulic equipment for the elevators.

C. Miscellaneous Spaces

1. Electric Rooms
Space for station electrical equipment should be provided at the lobby level. Fifty square feet should be programmed for electrical distribution rooms containing primarily power and lighting panels. If equipment requirements also include switchgear and transformers, a room should be provided at street level or special access provided to allow equipment replacement from the street level.

2. Mechanical Equipment Rooms
Provision must be made to accommodate station drainage and ventilation equipment. Location and size of mechanical rooms is dependent on detail design requirements.

3. Porter's Room
Rooms for maintenance and supply storage should be provided in the paid lobby area and the transit platform level. Porter's rooms should be between 75 and 100 square feet each.

4. Emergency Generator Room
As with other large electrical equipment requirements, a separate emergency generator room should be provided at street level or special access provided to allow equipment replacement from the street level.

5. Battery Room
A separate room containing station battery and charger/inverter unit and panel should be located near electrical and emergency generator rooms.

B. Proposed Schemes

Three alternate schemes have been developed. They represent the widest range of possible solutions. Major components of all schemes are in some cases interchangeable and may be recombined to generate additional sub-alternate schemes. For example, some of the platform, track and tunnel portions can be combined with fare collection and circulation areas from other schemes.

1. Scheme 1

Scheme 1 is based on a design concept produced by the MBTA in 1977. The Station area is shown in Figures 16 and 17. The lower level and track and tunnel configuration is shown in Figures 8 and 9. This scheme is not dependent on any major changes to vehicular circulation within Charles Circle. Street level entrances are located adjacent to the Charles Street Jail and on the east corner of Charles Street. the underground passageways are short, direct, and form the unpaid circulation area at the center of the new station lobby. The lobby, including paid and unpaid circulation zones, fare collection and service spaces is located at the Blue Line platform level. Three tracks and two platforms serve the new station. In this scheme, the station is set back to the east more than 100 feet from the existing Charles Station. Arrangement of vertical circulation between new and existing platform levels is direct without intermediate stops. The passenger travel distance from the midpoint of both platforms is about 660 feet. Escalators, stairways and elevators rise up at street level to clear the eastern most traffic lane under the Red Line viaduct. They terminate at the existing elevated Red Line platform level, 150 feet east of the headhouse. New, enclosed walkways are required to connect the vertical circulation to the present station. It is proposed that the walkways be clad in a metal skin, profiled to match the existing copper platform canopy enclosure. They would screen the existing copper enclosure and the existing viaduct and form a continuous tube beginning at the Longfellow Bridge and ending at the eastern edge of Charles Circle. The appearance of the existing headhouse would remain unchanged except for possible restoration work.

Enclosure for the elevator shafts and potentially the escalators and stairways could be of stone/precast concrete composite or cast in place concrete with a pronounced joint pattern to echo the granite block patterns of the Longfellow Bridge abutments and the walls of the Charles Street Jail. These enclosures would provide an anchor for the end of the station. They could be designed as tower like terminations that recall the towers of the Bridge.

2. Scheme 2

Scheme 2 provides the shortest walking distance between the Red and Blue Line Stations of the 3 schemes. The platform center to platform center distance is 460 feet. The Scheme 2 station and tunnel is shown in figures 10, 11, 18, and 19. The scheme is not dependent on any major changes to vehicular circulation within Charles Circle. Street level entrances are located on the north and south sides of the Circle in approximately the same places as Scheme 1. The underground passageways are longer than in Scheme 1 due to the need for a single fare collection zone accessible from both entrances. The lobby, located at the Blue Line platform level, includes paid and unpaid circulation zones, fare collection and service spaces. Two tracks and a center loaded platform serve the new station. Arrangement of vertical circulation between the Red and Blue Line platform levels is direct. In this scheme, the existing headhouse is demolished and replaced with a new structure containing the elevators, escalators and stairways. The enclosure could be stone/precast concrete composite or cast-in-place concrete similar to that proposed for Scheme 1. The scale of this new structure would provide an appropriate termination for the end of Charles Street as well as a strong anchor for the end of the station. The design concept for this anchor could acknowledge the existing towers of the Longfellow Bridge.

3. Scheme 3

Scheme 3 also extends the proposed Blue Line Station closer to the existing Charles Station than Scheme 1. Passengers' travel distance between the Red and Blue Line platforms is about 515 feet. This scheme which is shown in Figures 12, 13, 20, 21 and 22 is dependent on major improvement to vehicular circulation in Charles Circle including the creation of a single, large traffic island. As with Schemes 1 and 2, the street level entrances are located on the north and south sides of the Circle. The underground passageways are short, direct and lead into the station lobby located on a mezzanine level 15 feet above the Blue Line platform level. Introduction of an intermediate entry level is intended to shorten the actual and perceived travel distance from street level to the Red Line platforms. Patrons in the unpaid circulation zone mezzanine can see the Blue Line platform below, before they enter the fare collection area. Beyond the turnstiles they proceed to the paid circulation space and turn right or left to approach the stairs, elevators and escalators leading down to the Blue Line platform or up to the inbound and outbound Red Line platforms. As in Scheme 2, the existing headhouse will be demolished. The new headhouse structure is designed to be a dominant visual object in a redesigned Charles Circle. It would be constructed of stone, precast or cast-in-place concrete. The architectural vocabulary and scale would harmoniously relate to the Longfellow Bridge and Charles Street Jail. The headhouse would again becomes an integral part of Charles Circle, a formal termination for Charles Street and a visual landmark for Cambridge Street.

V. ENVIRONMENTAL ISSUES

A. Land Aquisition

Property required for the new tunnel and station is primarily within the road bed of Cambridge Street and Charles Circle. Use of the streets will require an agreement with the City of Boston and the Metropolitan District Commission, which has jurisdiction over Charles Circle.

The above ground structure connecting the Red Line Station platforms to the Blue Line will require reconfiguration of the central Charles Circle island and traffic patterns in the circle to varying degrees for each of the proposed station schemes. Scheme 1 has the least impact on the road configuration as the only substation revision affects the sidewalk area between Charles Street and West Cedar Street on the south side of the Circle. This enlargement of the sidewalk area also occurs in the other two schemes.

Scheme 2 modifies the road heading southbound under the viaduct which primarily serves traffic exiting Storrow Drive southbound. The two ramps exiting Storrow Drive are reconfigured into one ramp in Schemes 2 and 3. This change is recommended as a traffic improvement over the current vehicular flow where the left hand road is for right turns and the right is for northbound traffic.

Enlargement of the Central Circle in Scheme 3 affects the configuration of almost all roadways approaching the circle. In this scheme the southbound road under the viaduct is moved to the west. The two two-lane northbound roads under the viaduct are moved to east, with one of the roads reduced to one lane.

From visual observation during the evening rush hour it appears these schemes would not affect the level of service or safety of this intersection. Review with MDC and a complete capacity analysis of these intersection schemes will be required.

The two pedestrian tunnel entrances will replace the nearby overhead walkway stairs. The new entrance to the south will be in the sidewalk area in the three schemes proposed in this study. The traffic pattern and curb area will require reconfiguration which will require review by the MDC and the City of Boston. The northern pedestrian tunnel will require acquisition of property and easements in the parcel on the northeast corner of Charles Street and Cambridge Street. The subway entrance location may require demolition of the sandwich shop which is located on this parcel.

B. Impact on Surrounding Properties and Utilities

1. Impact on Surrounding Properties

After completion of the construction and opening of the Station, there will be a beneficial impact on the surrounding community due to increased transit accessibility. With the exception of the Charles Street Jail site and development of Massachusetts General Hospital (MGH) the area's development will probably remain stable. The land use on the north side of Cambridge is commercial and institutional, including a hotel and shopping center, parking garages, gas stations and several buildings used by Massachusetts General Hospital. Near Charles Circle there are several multistory office buildings, some with retail use on the first floor. On the south side of Cambridge Street there are mostly commercial use structures which border Beacon Hill. Closer to the circle on the south side there are some residential buildings. The Charles Street Jail site will be either developed for use by MGH or be the site of a new jail. If the site is developed as part of MGH, there can be a direct underground connection between the proposed station and the hospital. The planners of MGH have indicated that the lowest public level of the hospital will be at Elevation 13, which is about 7 feet below the sidewalk at Charles Circle. Ramping and other vertical circulation within the hospital site will be required to bring a connecting corridor down to the level of the pedestrian access tunnel to the subway station. The development of MGH to the north of the jail site includes a new inpatient services building facing Charles Street and an improved vertical circulation core serving the new and older portions of the main hospital complex.

During construction, mitigating measures will be required to alleviate interruptions of pedestrian and vehicular traffic and to provide continuity of access to buildings adjacent to the project site. A phasing plan for construction will be required to provide continuity of vehicular access to the hospital, fire station, gas stations and off-street parking. Requirements for vehicular deliveries to impacted buildings will require identification and all buildings will require pedestrian access. Provision for these access requirements and the traffic maintenance requirements is feasible with the proposed modular traffic decking system which would cover most of the excavation area requiring vehicular traffic. The modular deck units can be removed when required for construction work and then replaced. They would be designed to allow construction to take place underneath active traffic areas. Pedestrian traffic can be maintained with temporary walkways. In some areas there will be requirements for temporary construction easements up to building lines or 10 feet from construction areas.

Generally to characterize the impact of the construction, it can be described as a decked over roadway on Cambridge Street to the west of Staniford Street and in Charles Circle. There will be portions of the decking removed for construction and portions reserved for construction equipment and materials. The majority of the decked area will be reserved for traffic and access.

2. Impact on Utilities

The construction of the station and tunnel will require temporary and permanent relocation of some of utilities under Cambridge Street and Charles Circle and are assumed to be attainable through agreements with the affected utility companies.

The major telephone and electrical utilities within the project for the most part are located above the proposed tunnel roof and could be supported in place. In some instances cables would require relocation although it appears that this can be done without cutting and splicing.

The main sewer along Cambridge Street will require demolition to allow construction. This requires that a new sewer be constructed before demolition.

The other utilities in the excavation area and its zone of influence will either require relocation or could be supported in place. The extent of this work requires discussion with the affected utilities and further design refinement.

C. Impact on Traffic and Air Quality

The area of the study includes Cambridge Street and Charles Circle. Cambridge Street is a heavily used artery connecting Cambridge to Boston by means of the Longfellow Bridge. This artery at Charles Circle interacts with Charles Street and Storrow Drive. The traffic along Cambridge Street is sufficiently heavy that most of Cambridge Street will need to be made available during construction for purposes of providing sufficient inventory space for cars during the rush hour. Most of the tunnel and station excavation area will need to be decked over for traffic with sections of the decking removed to allow construction as work progresses. At the undecked locations further analysis will be required to determine if the traffic can be handled in both directions by one or two lanes of traffic in each direction. There are currently three lanes of traffic in each direction. The review of existing automobile traffic counts in the Charles Circle Area and visual observation during the evening rush hour tends to indicate that the existing levels of traffic could be maintained during construction, provided that sufficient amount of car storage or inventory be provided along with temporary signalization.

When this project is progressed to the environmental impact statement phase and then into final design, additional traffic counts will be required in order to determine to a greater degree of detail what measures will be required. Also during these later phases the air quality will require evaluation for the construction period and after the construction period. Due to the increased amount of traffic congestion during construction, it is assumed that the air quality will be temporarily affected due to more cars standing in traffic and operating at slower speeds. After construction the street configuration will be relatively unchanged from the present and provide the same level of service as the current configuration. Therefore, it is assumed that the related air quality impact will remain unchanged unless there are other outside factors which may increase or decrease the amount of traffic in this area.

D. Noise and Vibration

Construction will create noise and vibration impacts and may result in minor architectural and structural damage to the buildings in the vicinity of the construction. These impacts are generated mainly by pile driving, jackhammering, impact hammer and construction equipment. These impacts can be minimized by selecting construction methods and equipment carefully. Consideration should be given to preaugering piles, shrouding of pile drive heads, using temporary noise barriers and restricting times of operation.

E. Water Quality

The water quality will remain unchanged provided that proper techniques are taken during construction to settle any sediments that might be borne by water pumped out of the excavation. The recommended excavation and support methods will, for the most part, prevent a good amount of the ground water from entering the excavation. Pumps will be required to pump the remainder into the existing storm drainage system in the Charles Circle area. The turbidity of the water can be reduced by providing settling pits. The quality and quantity of the water discharged should be similar to the other storm runoff in the area.

F. Historic Context

The immediate vicinity of Charles Circle is rich in examples of historical and architectural significance. Beacon Hill borders on the southeast quadrant of the Circle. This entire neighborhood is designated as a historic district under the jurisdiction of the Boston Landmarks Commission. Charles Street Jail is located opposite the present station. The jail is a monumental, granite, rennaissance-revival structure completed in 1851. It is listed on the national and state historical registers. The station, station viaduct, and the Longfellow Bridge are all within the boundaries of the Charles River Basin National Historic District and as such modifications to any of these pieces require the approval of the

bridge itself, built in 1906, is considered historically significant is further protected by the Boston Landmarks Commission. The station proper including the viaduct, support piers and headhouse was completed in 1932. It is not considered historic or architecturally significant by the Landmarks Commission or the Massachusetts Historical Commission. However, the granite retaining walls which support the west end of the station platforms are part of the Longfellow Bridge and are included in the historic designation. Any proposed construction at or adjacent to the granite retaining walls is subject to a formal review by the Landmarks commission. Although they have no other official interest in the present station, the Boston Landmarks Commission, the Massachusetts Historical Commission as well as the Beacon Hill Civic Association, BRA and other interested parties should participate in public reviews of this project.

VI. OPERATIONAL COST

A. Train Crew and other Transportation Employee Costs

1. Additional Cycle Time

It is estimated that the additional running time from Bowdoin to the new Charles Street Station will be approximately one minute. Adding 4 minutes of dwell time at the new Charles Station for changing ends plus 30 seconds each way at Bowdoin for station dwell time (now included in the layover allowance at this terminal), results in a total time of 7 minutes for a round trip form Bowdoin's inbound platform to Charles Station to the Bowdoin outbound platform.

With some exceptions that are both longer and shorter, current schedules on the Blue Line are based on a 45 minute round trip cycle time (the time between successive departures of the same train from the same terminal). Of this, some 36 minutes represent running time (including station dwell time) with the layovers being divided 2 minutes at Bowdoin and 7 minutes at Wonderland. Subtracting the 2 minutes allowed at Bowdoin presently from the 7 minutes derived previously for the extension to Charles Station results in a net increase in round trip cycle time due to the extension to Charles Station of some 5 minutes.

2. Crew Scheduling

The annual operating cost for train crews shown in Exhibit 16 are based on the following assumptions:

Weekdays:

Although not absolutely uniform, peak period headways on the Blue Line approach 3 minutes in both the AM and PM peaks. Since the additional cycle time is greater than one headway, it would appear that 2 additional crews would be required to maintain the same frequency of service. In off-peak periods, at least one additional crew will be required to maintain the present 7.5 minute average midday headway. However, to avoid unnecessary pay hours beyond the time covered by two shifts, there are several options which will allow the MBTA to conserve on crew costs. For example, in the early morning and late evening periods either the cycle time could be shortened (reflecting the shorter dwell time due to reduced patronage during these hours) or headways could be lengthened slightly. It is assumed for purposes of this cost estimate, that these options are put into practice so that a fifth crew will not be needed.

Saturdays:

Current Saturday schedules call for 6 trains on a 45 minute cycle to provide a 7.5 minute average basic headway. To maintain the same headway with 5 minutes of additional cycle time will require one additional crew. Again, minor lengthening of headways and/or shortening of cycle times would probably be employed to avoid overtime beyond the one-shift crew coverage.

Sundays/Holidays

Sunday and Holiday schedules presently involve 4 trains on a 44 minute cycle providing a basic 11-minute headway. Lengthening cycle time by 5 minutes because of the extension to Charles Circle could be addressed either by lengthening the headway (to slightly over 12 minutes) or by adding a crew per shift which would allow a 10 minute headway. Assuming the goal of promoting the new extension by maintaining or improving headways, we have added the cost of one additional crew.

3. Inspector Coverage and Yard Motorman

The costs for Inspector coverage of the station and yard motorman coverage of the train storage area have been included in the cost estimate as separate costs to allow the MBTA to evaluate the impact of providing this coverage. The estimate is based on providing 140 hours a week coverage by inspectors and one shift coverage for the yard motorman.

B. Electric Power Costs

Power requirements include vehicle power consumption and station power for lighting, elevators, escalators and other equipment. The traction power estimate is based on an estimated 144,536 additional car miles traveled and 5.4 KW Hr/Car Mile traction power usage. The car auxiliary power requirement is based on 16,060 additional car hours and 30 KW Hrs. auxiliary load. An 90% efficiency of power conversion and distribution was assumed for both vehicle power requirement. The cost for this power at 7.9 cents per KW Hr. is shown in Exhibit 16. The following additional annual car miles for both a 4 car train operation and six car train operation were used in estimating these costs:

Additional Annual Car Miles

	4 Car Trains	6 Car Trains
Weekdays	118,125	151,500
Saturdays	17,472	17,472
Sundays/Holidays	8,939	8,939
Total Additional Annual Car Miles	144,536	177,911

The existing Red Line Station power supply at Charles is not sufficient to supply the needs of a combined station for both the Red and blue Lines. In Exhibit 16 the cost estimate for station

power is based on purchase of power with a 480 volt 3-phase service and an average 85% power factor for all devises.

C. Station Cleaning

The existing Red line station fare collection area and passageways would be replaced with a new, enlarged and combined fare control and entrance area for both the Red and Blue Lines plus a new Blue Line platform area.

The cost in Exhibit 16 assumes an increased cost for contract cleaning.

D. Station Operations

Since the new combined Red and Blue Lines station would replace the existing Red Line fare control, no additional cost for station personnel or fare collection maintenance has been allowed.

E. Station Apparatus

Again, since the basic station structure would be a direct replacement for the existing Red Line station, no additional maintenance is assumed. However, since the new station would have 3 elevators and 6 escalators that are not present in the existing station, the costs of maintaining this apparatus is included.

F. Station Lamp Maintenance

The cost of station lamp maintenance is based on replacement of lamps on a three year cycle.

G. Vehicle Maintenance Costs

The vehicle maintenance cost is based on providing 144,500 additional car miles with an assumed maintenance cost per mile of 70 cents per mile.

EXHIBIT 16

BOWDOIN - CHARLES STREET STATION
CONNECTOR PROJECT FEASIBILITY STUDY

ANNUAL OPERATING COST ESTIMATE
(1986 DOLLARS)

COST SUMMARY

Train Crews	$ 262,000
Inspector	180,500
Yard Motorman	44,500
Traction Power - Present Schedule	111,000
Station Power	147,100
Station Cleaning	43,200
Station Apparatus	102,600
Station Lamp Maintenance	3,100
Vehicle Maintenance	101,200
Total Operating Cost	$ 995,200
say	$ 995,000

VII. CONSTRUCTION COST ESTIMATE

A. Basis of Estimate

The construction cost estimate is based on current Boston construction prices as well as the experience of the Project Consultant and Sub Consultants. In addition to the basic construction cost, 20% has been added for contingencies. This is a standard cost estimating practice for this stage of project development and provides an allowance for future cost refinements due to staging and construction requirements.

The prices are based on 1986 dollars and will be subject to escalation to the construction date for the project. Based on recent trends, escalation of construction costs are assumed to be 6% per annum. The ultimate project costs will depend on the actual construction schedule. The start of construction will be influenced by the availability of funds and completion of an environmental impact statement and final design.

B. Other Capital Costs

Besides the cost of construction contracts, other capital costs include architectural and engineering design costs, construction management, agency costs (MBTA and others if required), land acquisition, easements, betterments and a reserve for changes during construction. There should be no cost for additional rolling stock as the existing fleet is deemed sufficient to provide service for the addition of one Blue Line Station at Charles Circle. Substation costs have not been identified as it is assumed that there is sufficient capacity at the existing Haverhill Street and Kendall Substation.

C. Construction Cost Estimate

Exhibit 17 summarizes the construction costs for major construction elements for the three schemes proposed in this Final Report. The costs have been revised since the previous report to incorporate addiitional signal work for a powered remote controlled turnout west by Bowdoin Station and to provide double direction running. In addition, the costs for scheme 3 has been revised due to the addition of a third RAD train storage track.

EXHIBIT 17
BOWDOIN STATION-CHARLES STREET STATION
CONNECTOR PROJECT FEASIBILITY STUDY
CONSTRUCTION COST ESTIMATE
(1986 Dollars)

	Scheme 1	Scheme 2	Scheme 3
1. Public Protection and General Requirements	$ 1,992,000	$ 1,992,000	$ 2,192,000
2. Demolition, Earthwork & Earth Support Systems	20,500,000	20,495,000	23,253,000
3. Traffic Decking	7,060,000	7,045,000	7,945,000
4. Utility Relocation and Traction Power Duct Bank	6,244,000	6,258,000	6,873,000
5. Roadway Restoration and Landscaping	1,739,000	2,412,000	3,074,000
6. Concrete and Moisture Protection	9,910,000	12,153,000	13,218,000
7. Structural Steel and Miscellaneous Metals	7,012,000	6,310,000	8,606,000
8. Trackwork	1,411,000	1,444,000	1,546,000
9. Station Finishes and Specialties	2,524,000	2,235,000	4,213,000
10. Elevators, Escalators and Mechanical Systems	1,652,000	1,652,000	2,190,000
11. Signals, Communications and Electrical Systems	5,669,000	5,422,000	5,869,000
Subtotal	65,713,000	67,418,000	78,979,000
Contingency (20%)	13,143,000	13,484,000	15,796,000
TOTAL	$78,856,000	$80,902,000	$94,775,000

LEGEND:

854 — DESIGNATION AND APPROXIMATE PLAN LOCATION OF A TEST BORING OBTAINED FROM PUBLICATIONS OF BOSTON SOCIETY OF CIVIL ENGINEERS.

719 — DESIGNATION AND APPROXIMATE PLAN LOCATION OF A TEST BORING CONDUCTED UNDER PREVIOUS MBTA CONTRACT.

718 — TEST BORING NUMBER

EL.130 — APPROXIMATE GROUND SURFACE ELEVATION.

WATER LEVEL OBSERVED IN TEST BORING UPON COMPLETION OF THE BOREHOLE.

12 — APPROXIMATE LOCATION OF 1-3/8 IN. I.D. BY 2 IN. O.D. SPLIT-SPOON SAMPLER DRIVEN WITH A 140 LB. HAMMER FALLING 30 INCHES. NUMBER INDICATES BLOWS PER FOOT.

APPROXIMATE LOCATION OF STRATA CHANGE.

REF — REFUSAL; NO PENETRATION WITH OPEN-END ROD OR SPLIT-SPOON SAMPLER.

BOE — BOTTOM OF EXPLORATION

STRATUM DESIGNATION	GENERALIZED DESCRIPTION
A MISCELLANEOUS FILL	HETEROGENEOUS AND INTERMIXED, PREDOMINANTLY GRANULAR, MAN-MADE FILL, WITH VARYING AMOUNTS OF GRAVEL, SILT, CLAY, AND TRACE AMOUNTS OF BRICK, CINDER, STONE AND CONCRETE.
B TIDAL MARSH DEPOSITS	GENERALLY CONSISTS OF LOOSE TO VERY LOOSE ORGANIC SILT, SILTY FINE SAND AND PEAT. MAY ALSO CONTAIN SHELLS AND LITTLE TO TRACE CLAY, COARSE SAND AND GRAVEL.
MARINE DEPOSITS	STRATUM VARIES AT SPECIFIC LOCATIONS IN THE FIELD AND GENERALLY CONSISTS OF:
C_1 SAND AND GRAVEL	PREDOMINANTLY MEDIUM DENSE TO DENSE SILTY FINE SANDS AND GRAVEL WITH INTERBEDDED CLAY AND SILT.
C_2 SILTY CLAY	PREDOMINANTLY VERY SOFT TO VERY STIFF SILTY CLAY WITH INTERBEDDED SAND AND GRAVEL. THIS DEPOSIT TYPICALLY EXHIBITS AN UPPER DESSICATED YELLOW SILTY CLAY LAYER CONTAINING A HIGHER PROPORTION OF SAND AND GRAVEL LENSES, GRADING INTO A BLUE SILTY CLAY BELOW.
D GLACIAL TILL	GENERALLY CONSISTS OF MEDIUM TO VERY DENSE SILTY CLAY, SAND AND GRAVEL WITH ROCK FRAGMENTS AND BOULDERS.
E BEDROCK	TYPICALLY CONSISTS OF HARD TO SOFT CAMBRIDGE ARGILLITE.

NOTES:

1. TEST BORINGS INCLUDED ON THE PLAN AND PROFILE WERE CONDUCTED BY OTHERS PRIOR TO THIS STUDY.
2. SOURCES OF TEST BORING DATA INCLUDE:
   - o BOSTON SOCIETY OF CIVIL ENGINEERS, "BORING DATA FROM GREATER BOSTON", 1961.
   - o BOSTON SOCIETY OF CIVIL ENGINEERS, "JOURNAL OF THE BOSTON SOCIETY OF CIVIL ENGINEERS", JULY-OCTOBER 1969, VOLUME 56, NUMBER 3-4.
   - o BOSTON TRANSIT COMMISSION, THREE DRAWINGS ENTITLED "PLAN AND PROFILE, EAST BOSTON TUNNEL EXTENSION, SECTION J", DATED SEPTEMBER 1913.
3. THE GROUND SURFACE ELEVATION AT TEST BORING 1043 WAS NOT REPORTED. FOR INFORMATIONAL PURPOSES, THE DATA HAVE BEEN PRESENTED ASSUMING A GROUND SURFACE ELEVATION SIMILAR TO THAT OF BORING 1042.
4. SUBSURFACE PROFILE DRAWN BY PROJECTING TEST BORING INFORMATION TO THE APPROXIMATE CENTER OF CAMBRIDGE STREET BETWEEN CHARLES STREET STATION AND THE EXISTING BLUE LINE PORTAL AT JOY STREET. WEST OF THE STAIR STRUCTURE AT CHARLES STREET STATION, TEST BORING INFORMATION WAS PROJECTED TO THE RED LINE ALIGNMENT CENTERLINE. EAST OF THE BLUE LINE PORTAL AT JOY STREET, TEST BORING INFORMATION WAS PROJECTED TO THE BLUE LINE ALIGNMENT CENTERLINE.
5. LINES REPRESENTING CHANGES IN STRATA ARE BASED ON INTERPOLATION BETWEEN BORINGS AND MAY NOT REPRESENT ACTUAL SUBSURFACE CONDITIONS. STRATA LINES ARE DASHED WHERE INFERRED.
6. ELEVATIONS REFER TO MBTA DATUM, WHEREIN EL. 0.0 IS 105.65 FT. BELOW NATIONAL GEODETIC VERTICAL DATUM.
7. BASE PLAN PROVIDED BY STV/SEELYE STEVENSON VALUE & KNECHT, ENGINEERS AND PLANNERS.
8. APPROXIMATE LOCATIONS OF COLONIAL SHORELINE, 1795 WHARF LINE AND 1850 WHARF LINE OBTAINED FROM "PLAN OF BOSTON PROPER SHOWING CHANGES IN STREET AND WHARF LINES, 1795-1895", BY CHARLES C. PERKINS - SURVEYOR IN CHARGE OF CITY PROPER SURVEYORS, DATED 31 JANUARY 1895, SCALE: 1 IN. = 400 FT.

Bowdoin Station–Charles St. Station Connector Project–Feasibility Study

LEGEND AND NOTES FOR SUBSURFACE INFORMATION

HALEY & ALDRICH, INC.

STV/Seelye Stevenson Value & Knecht
Engineers and Planners

FIGURE 1

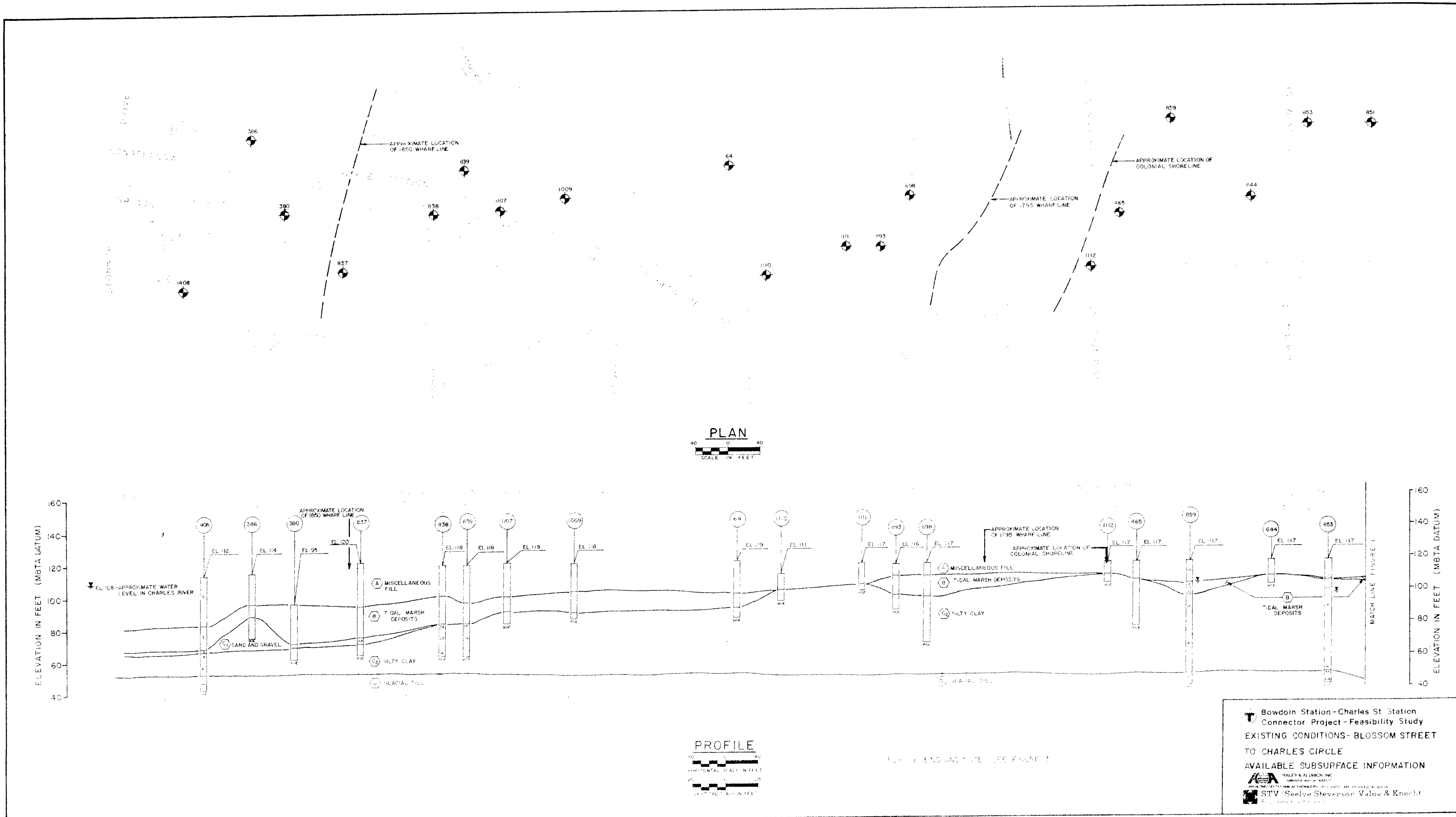
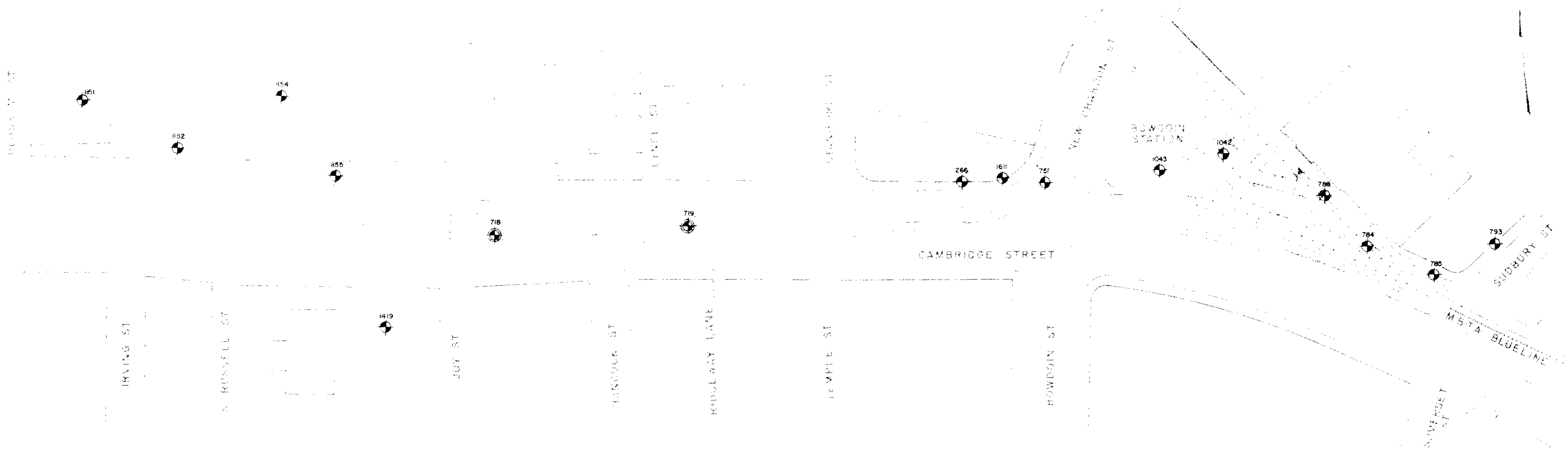
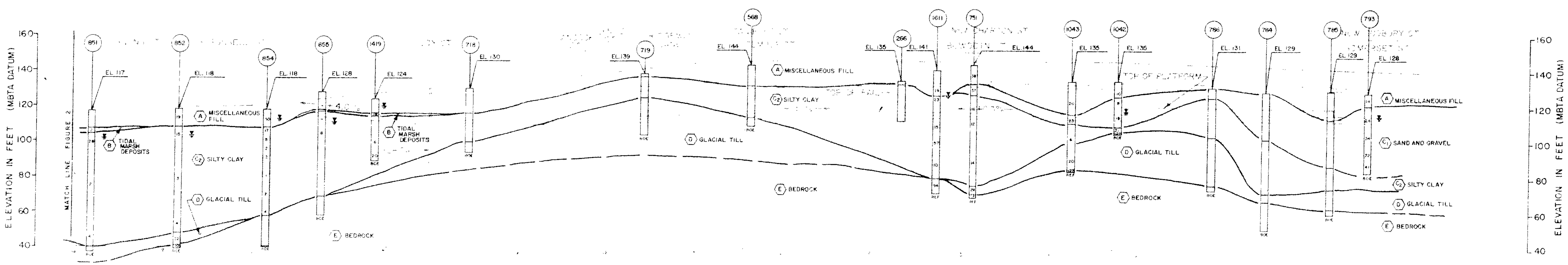

APPROXIMATE LOCATION OF 1850 WHARF LINE
APPROXIMATE LOCATION OF 1795 WHARF LINE
APPROXIMATE LOCATION OF COLONIAL SHORELINE
PLAN
SCALE IN FEET
ELEVATION IN FEET (MBTA DATUM)
EL 108 - APPROXIMATE WATER LEVEL IN CHARLES RIVER
MISCELLANEOUS FILL
TIDAL MARSH DEPOSITS
SAND AND GRAVEL
SILTY CLAY
GLACIAL TILL
MATCH LINE FIGURE 1
PROFILE
Bowdoin Station-Charles St Station Connector Project-Feasibility Study
EXISTING CONDITIONS-BLOSSOM STREET TO CHARLES CIRCLE
AVAILABLE SUBSURFACE INFORMATION
HALEY & ALDRICH, INC.
STV (Seelye Stevenson Value & Knecht

FIGURE 2



PLAN

40 0 40
SCALE IN FEET



PROFILE

40 0 40
HORIZONTAL SCALE IN FEET
20 0 20
VERTICAL SCALE IN FEET

FOR LEGEND AND NOTES SEE FIGURE 3

Bowdoin Station-Charles St. Station Connector Project-Feasibility Study

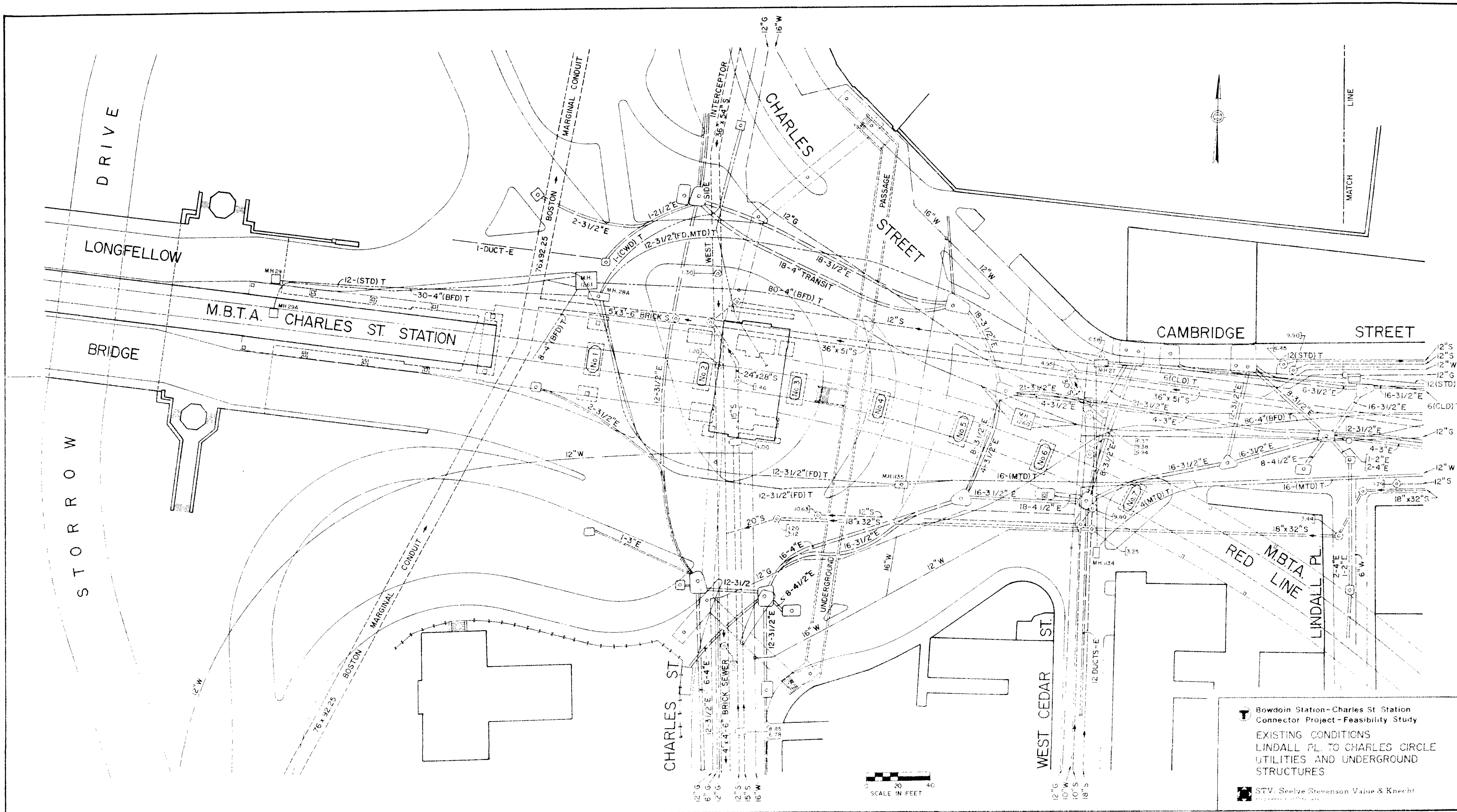
EXISTING CONDITIONS-BOWDOIN STATION TO BLOSSOM STREET

AVAILABLE SUBSURFACE INFORMATION

HALEY & ALDRICH, INC.
CONSULTING GEOTECHNICAL ENGINEERS, GEOLOGISTS AND HYDROGEOLOGISTS

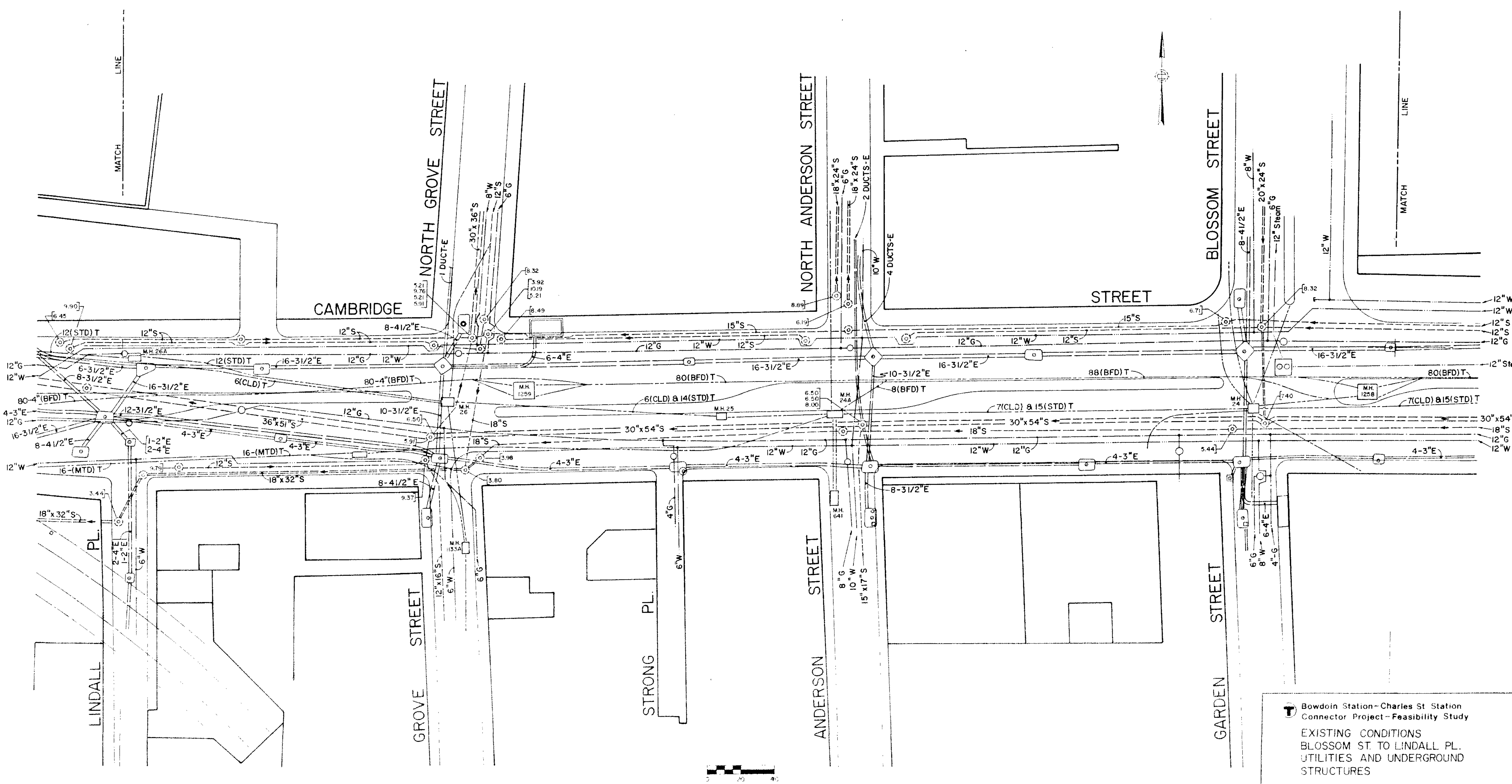
STV/Seelye Stevenson Value & Knecht
Engineers and Planners

FIGURE 3



Bowdoin Station–Charles St Station
Connector Project–Feasibility Study
EXISTING CONDITIONS
LINDALL PL. TO CHARLES CIRCLE
UTILITIES AND UNDERGROUND
STRUCTURES
STV/ Seelye Stevenson Value & Knecht
SCALE IN FEET
0
20
40
STORROW DRIVE
LONGFELLOW BRIDGE
M.B.T.A. CHARLES ST. STATION
CHARLES STREET
CAMBRIDGE STREET
WEST CEDAR ST.
CHARLES ST.
LINDALL PL.
M.B.T.A. RED LINE
BOSTON MARGINAL CONDUIT
76"x92.25
WEST SIDE INTERCEPTOR
36"x54" S
UNDERGROUND PASSAGE
MATCH LINE
4'x4'-6" BRICK SEWER
5'x3'-6" BRICK S.
36"x51" S
24"x28" S
18"x32" S
12"W
12"S
12"G
16"W
12 DUCTS-E
1-DUCT-E
80-4"(BFD) T
30-4"(BFD) T
18-4" TRANSIT
12-(STD) T
16-(MTD) T
12-31/2"(FD) T
12-31/2"(FD, MTD) T
No.1
No.2
No.3
No.4
No.5
No.6
No.7
M.H. 29
M.H. 29A
M.H. 28A
M.H. 1135
M.H. 1134

FIGURE 4



Bowdoin Station–Charles St Station Connector Project–Feasibility Study

EXISTING CONDITIONS
BLOSSOM ST. TO LINDALL PL.
UTILITIES AND UNDERGROUND STRUCTURES

STV Seelye Stevenson Value & Knecht

FIGURE 5

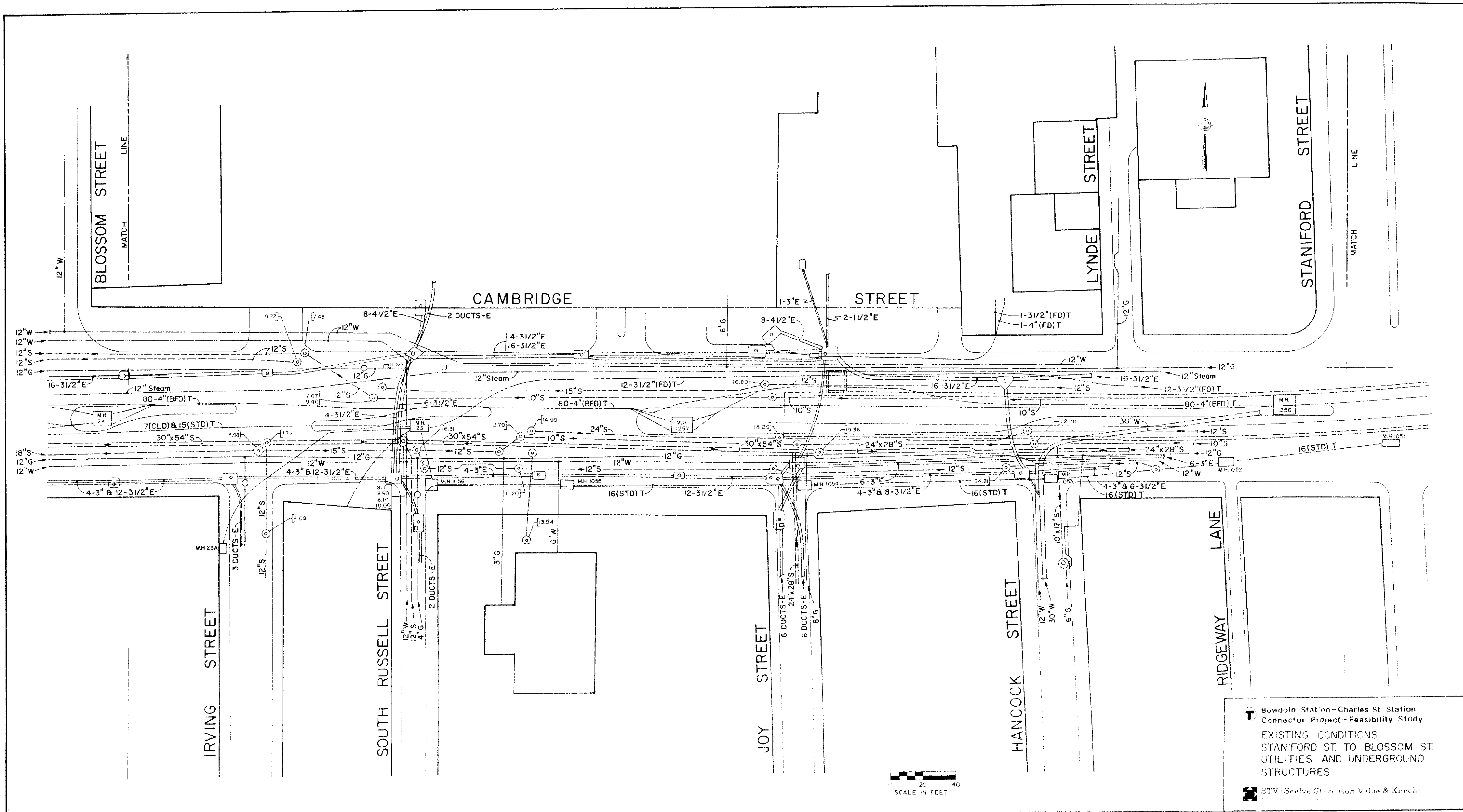
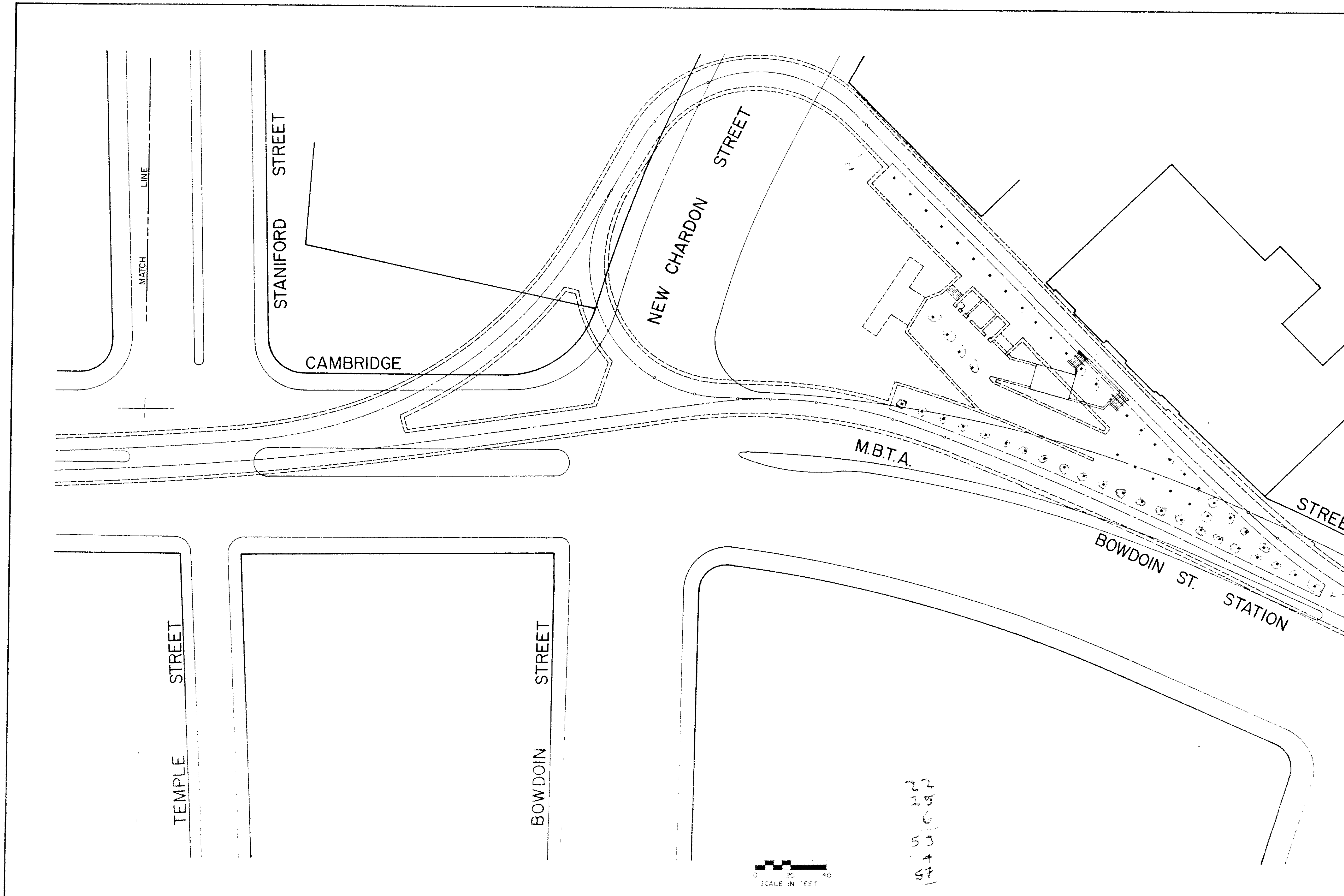

BLOSSOM STREET
MATCH LINE
CAMBRIDGE STREET
LYNDE STREET
STANIFORD STREET
MATCH LINE
IRVING STREET
SOUTH RUSSELL STREET
JOY STREET
HANCOCK STREET
RIDGEWAY LANE
M.H. 24
M.H. 23
M.H. 1056
M.H. 1055
M.H. 1257
M.H. 1054
M.H. 1053
M.H. 1256
M.H. 1051
M.H. 1052
M.H. 23A
12"W
12"S
12"G
18"S
16-31/2"E
12" Steam
80-4"(BFD) T
7(CLD) & 15(STD) T
30"x54"S
15"S
10"S
24"S
24"x28"S
30"W
16(STD) T
12-31/2"(FD) T
4-3" & 12-31/2"E
4-3" & 8-31/2"E
4-3" & 6-31/2"E
6-3"E
8-41/2"E
2 DUCTS-E
2-11/2"E
1-3"E
1-31/2"(FD)T
1-4"(FD)T
3 DUCTS-E
6 DUCTS-E
10"x12"S
Bowdoin Station–Charles St Station Connector Project – Feasibility Study
EXISTING CONDITIONS
STANIFORD ST. TO BLOSSOM ST.
UTILITIES AND UNDERGROUND STRUCTURES
0 20 40
SCALE IN FEET
STV Seelye Stevenson Value & Knecht

FIGURE 6



Bowdoin Station–Charles St Station Connector Project–Feasibility Study

EXISTING CONDITIONS
BOWDOIN STATION TO
STANIFORD STREET
UNDERGROUND STRUCTURES

STV Seelye Stevenson Value & Knecht

FIGURE 7

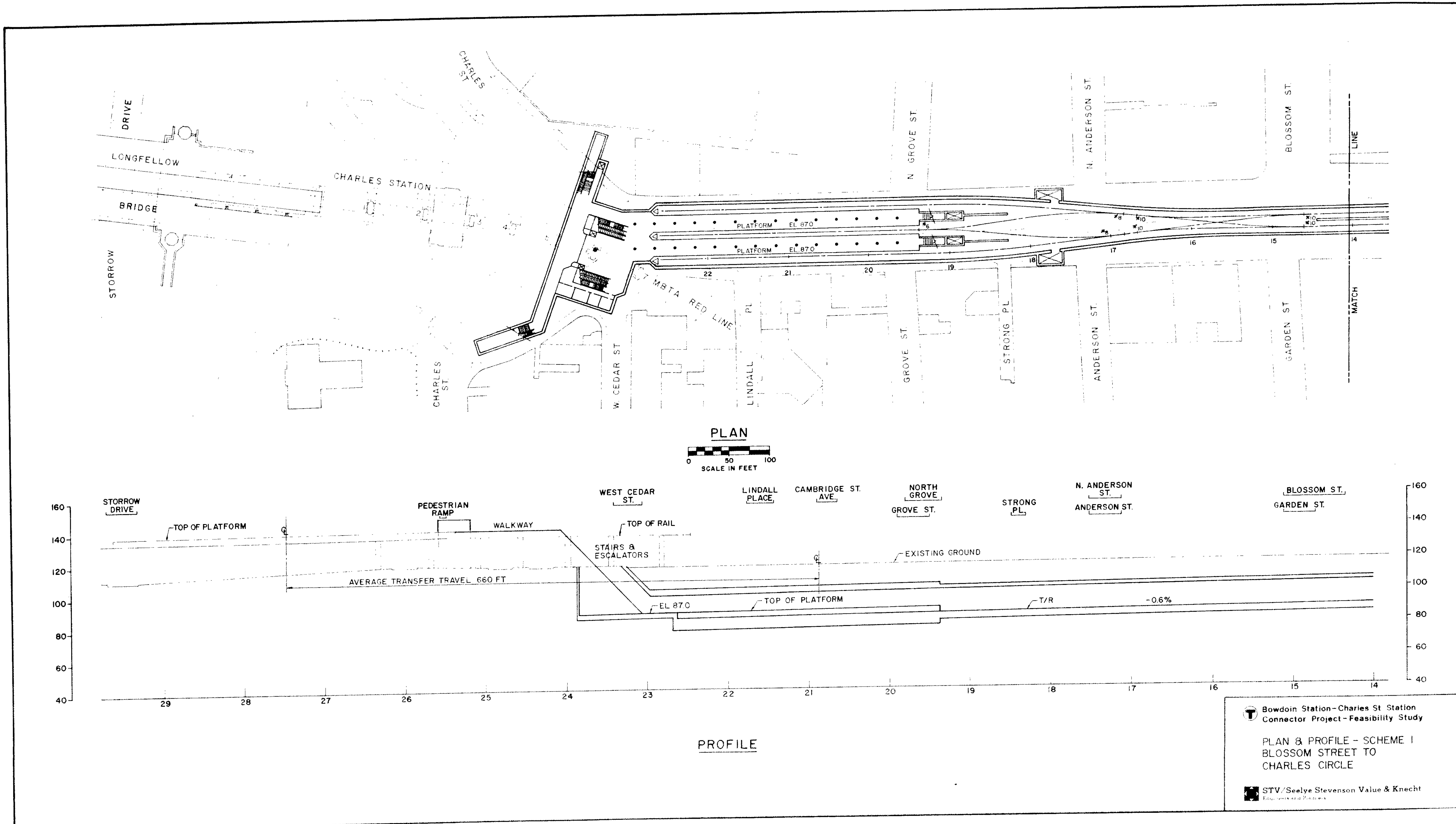
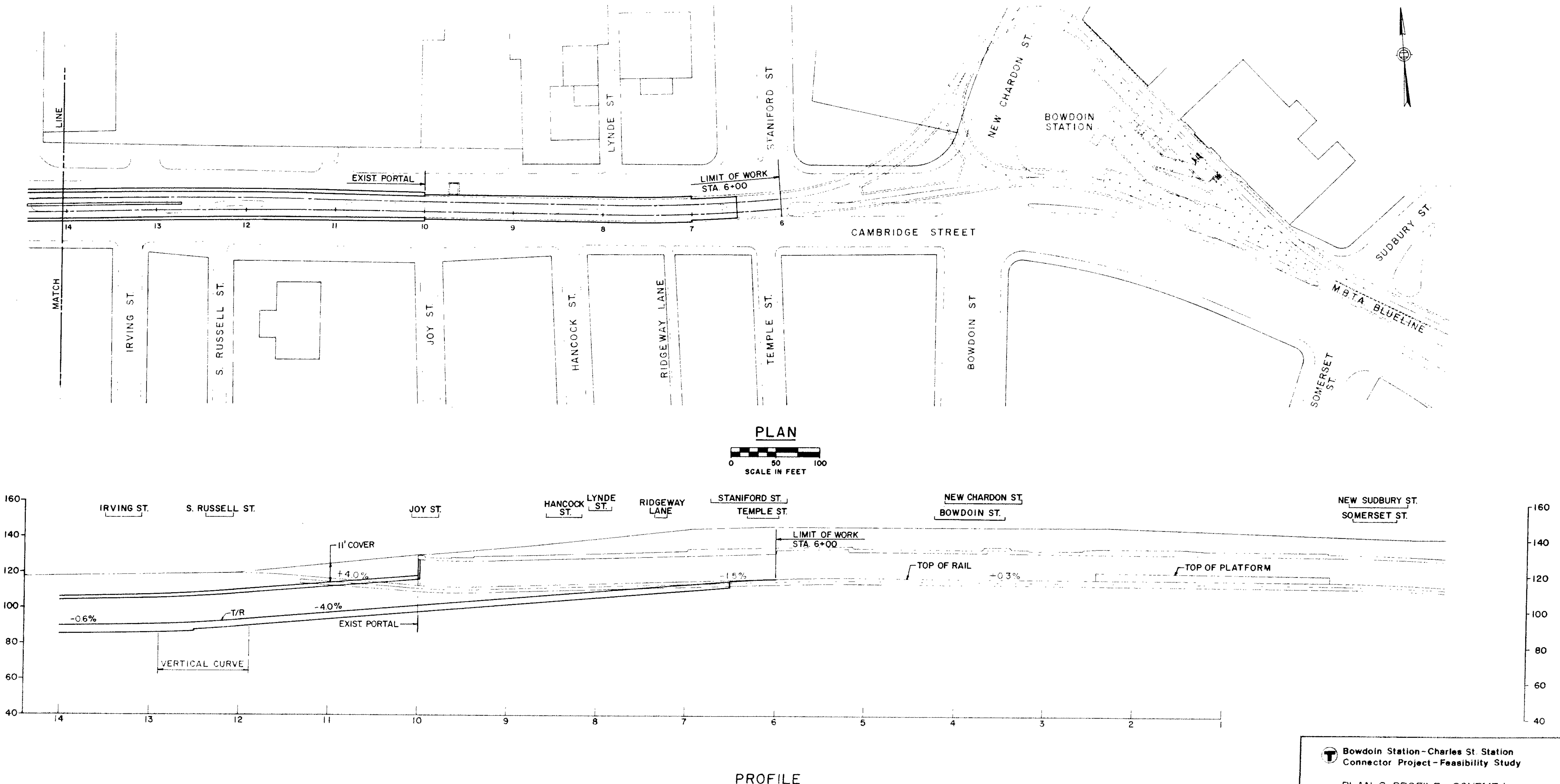

PLAN
PROFILE
SCALE IN FEET
0
50
100
STORROW DRIVE
LONGFELLOW BRIDGE
CHARLES STATION
CHARLES ST
N. GROVE ST
N. ANDERSON ST.
BLOSSOM ST.
MATCH LINE
PLATFORM EL 87.0
MBTA RED LINE
W. CEDAR ST
LINDALL PL
GROVE ST
STRONG PL
ANDERSON ST.
GARDEN ST
PEDESTRIAN RAMP
WALKWAY
TOP OF PLATFORM
WEST CEDAR ST.
TOP OF RAIL
STAIRS & ESCALATORS
LINDALL PLACE
CAMBRIDGE ST. AVE.
NORTH GROVE
GROVE ST.
STRONG PL.
EXISTING GROUND
AVERAGE TRANSFER TRAVEL 660 FT
EL 87.0
T/R
-0.6%
Bowdoin Station-Charles St Station Connector Project-Feasibility Study
PLAN & PROFILE - SCHEME I BLOSSOM STREET TO CHARLES CIRCLE
STV/Seelye Stevenson Value & Knecht

FIGURE 8

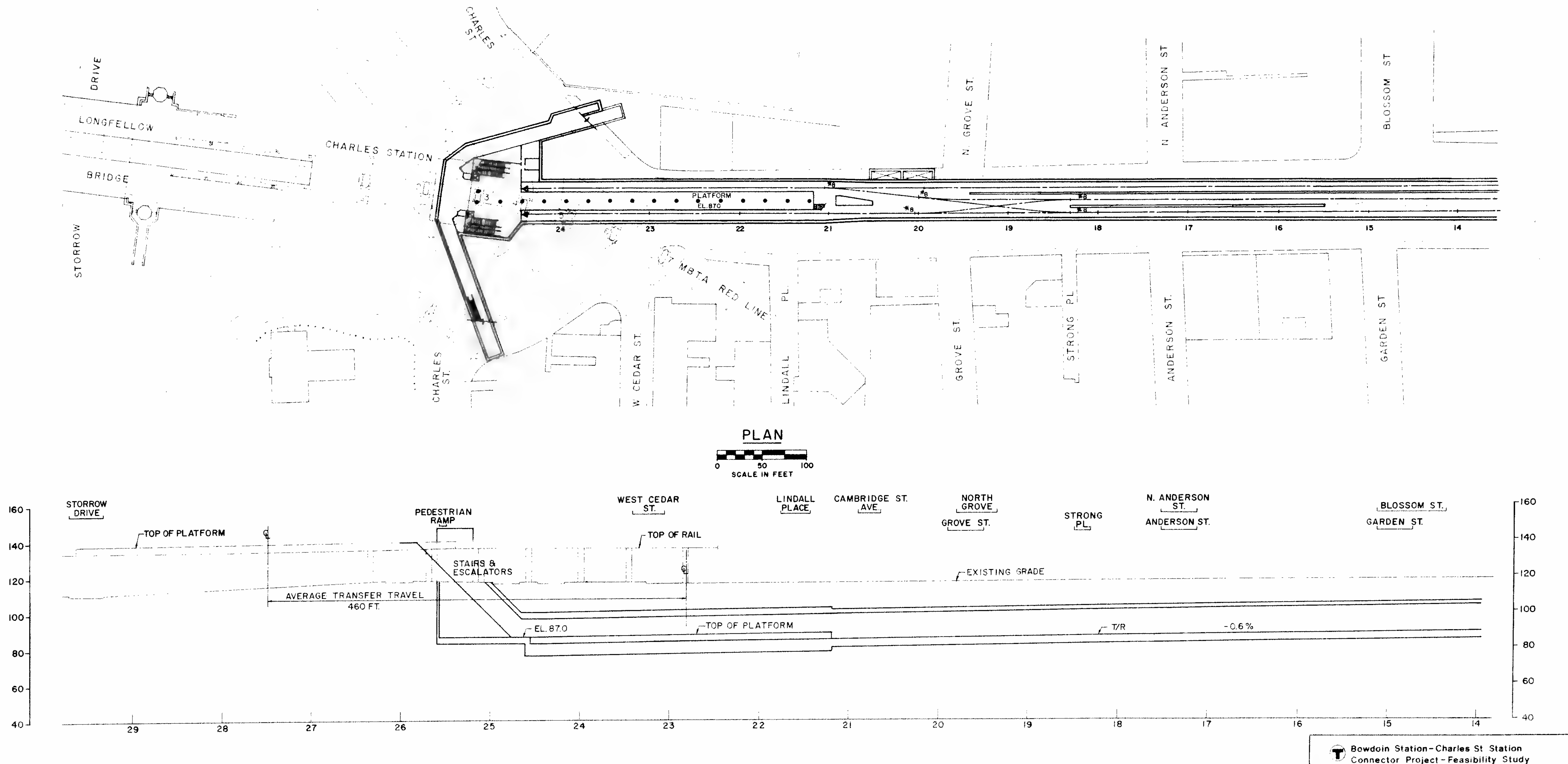


Bowdoin Station - Charles St. Station Connector Project - Feasibility Study

PLAN & PROFILE - SCHEME I
BOWDOIN STATION TO
BLOSSOM STREET

STV/Seelye Stevenson Value & Knecht

FIGURE 9

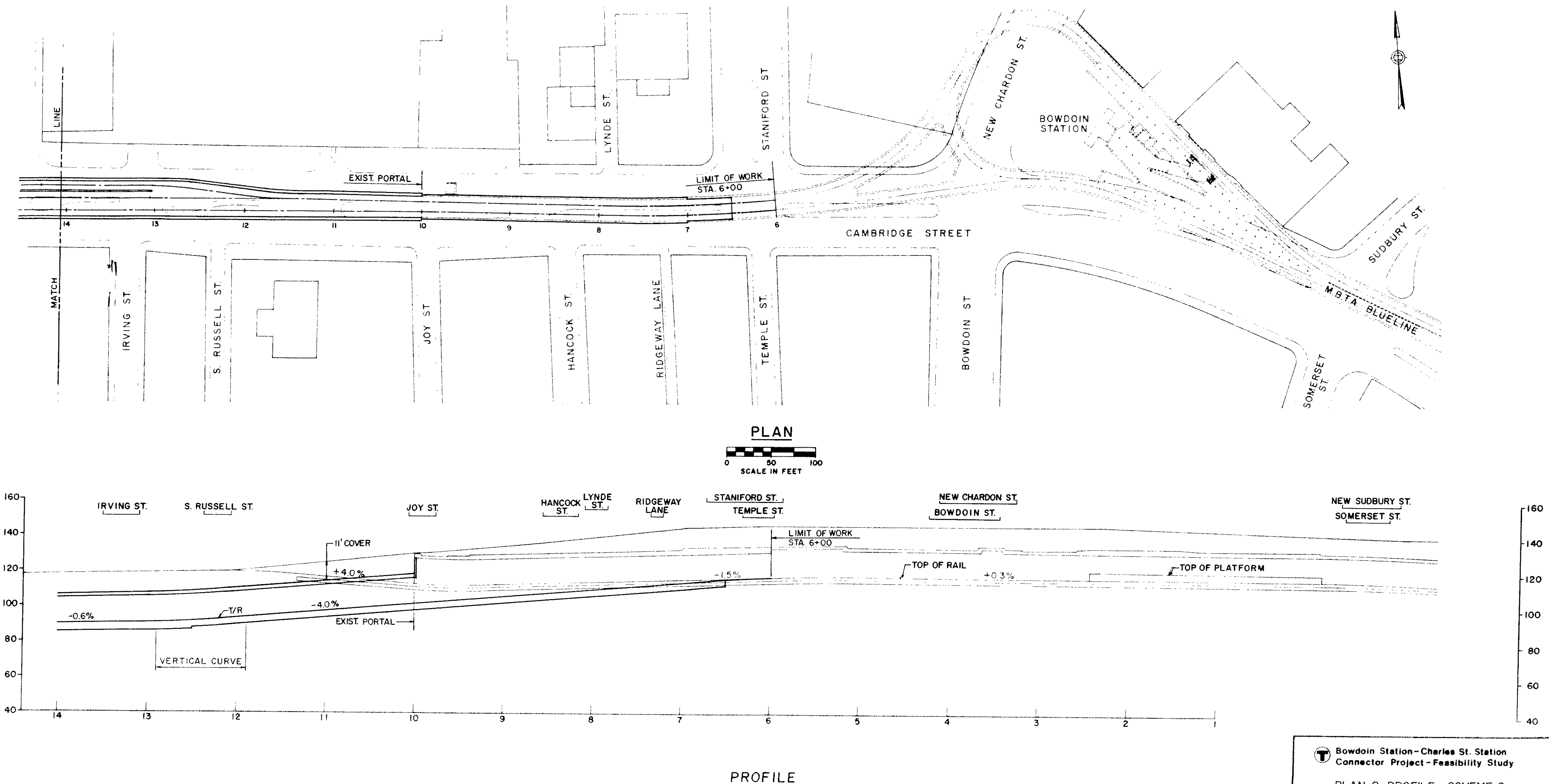


Bowdoin Station-Charles St Station Connector Project-Feasibility Study

PLAN & PROFILE - SCHEME 2
BLOSSOM STREET TO CHARLES CIRCLE

STV/Seelye Stevenson Value & Knecht

FIGURE 10

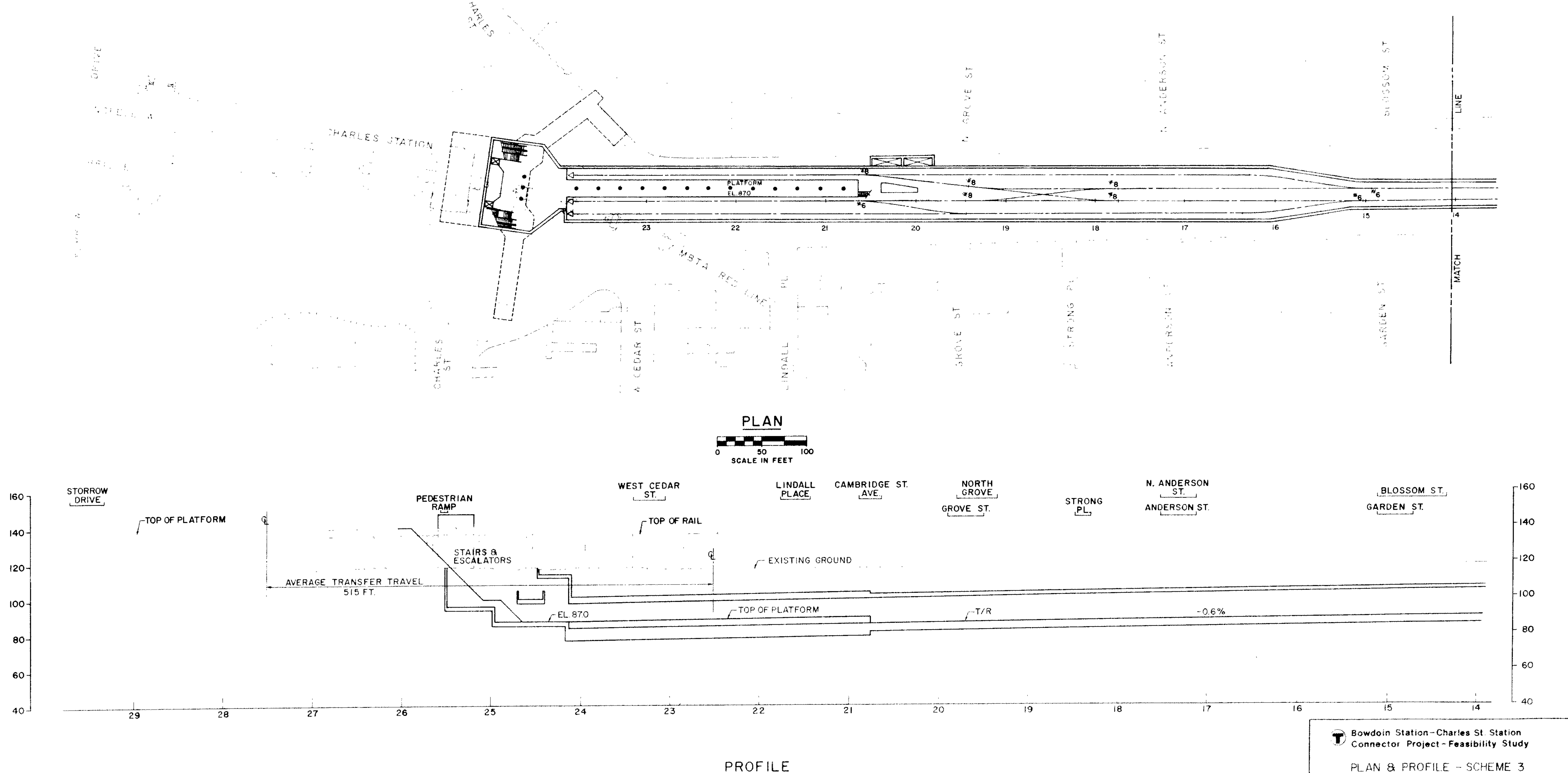


Bowdoin Station-Charles St. Station Connector Project-Feasibility Study

PLAN & PROFILE - SCHEME 2
BOWDOIN STATION TO
BLOSSOM STREET

STV/Seelye Stevenson Value & Knecht
Engineers and Planners

FIGURE 11

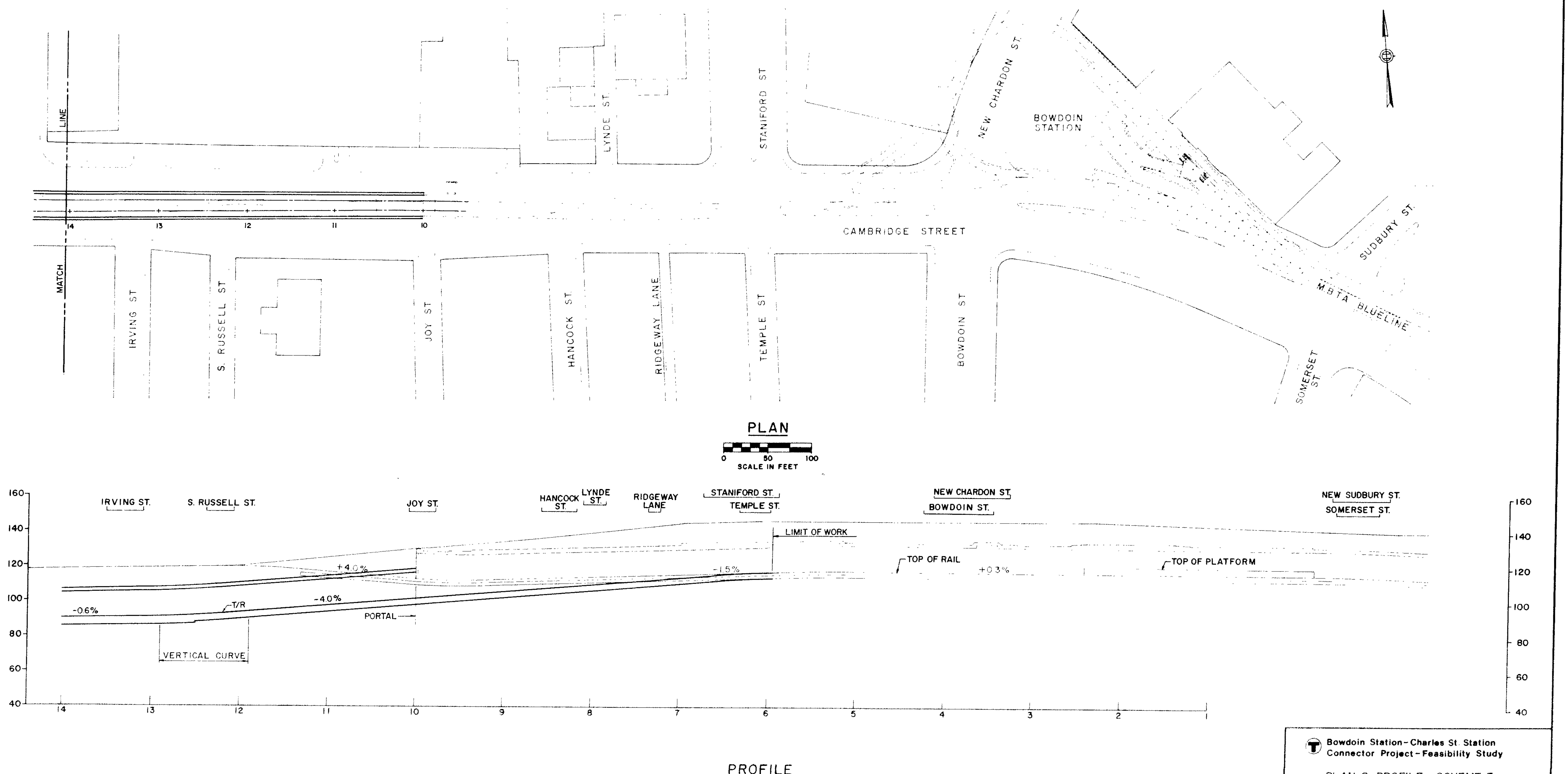


Bowdoin Station-Charles St. Station Connector Project - Feasibility Study

PLAN & PROFILE - SCHEME 3
BLOSSOM STREET TO
CHARLES CIRCLE

STV/Seelye Stevenson Value & Knecht

FIGURE 12

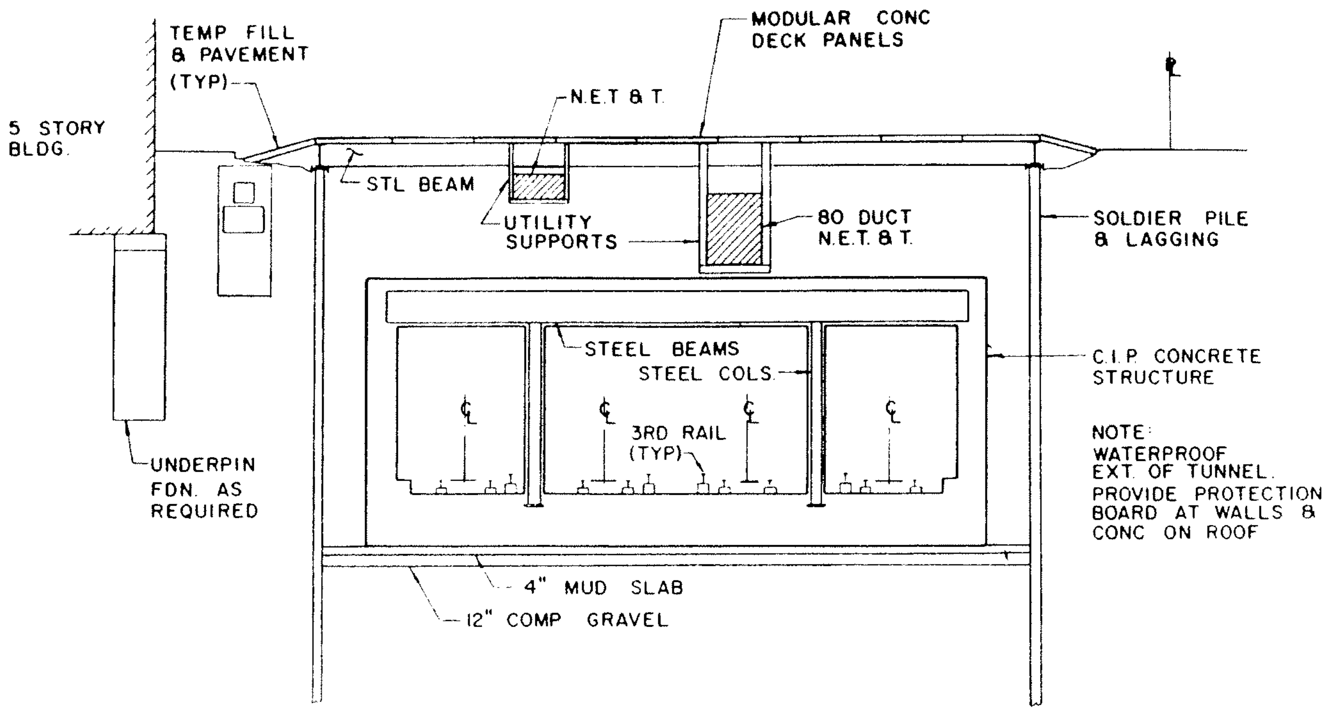


Bowdoin Station-Charles St. Station Connector Project-Feasibility Study

PLAN & PROFILE - SCHEME 3
BOWDOIN STATION TO
BLOSSOM STREET

STV/Seelye Stevenson Value & Knecht
Engineers and Planners

FIGURE 13

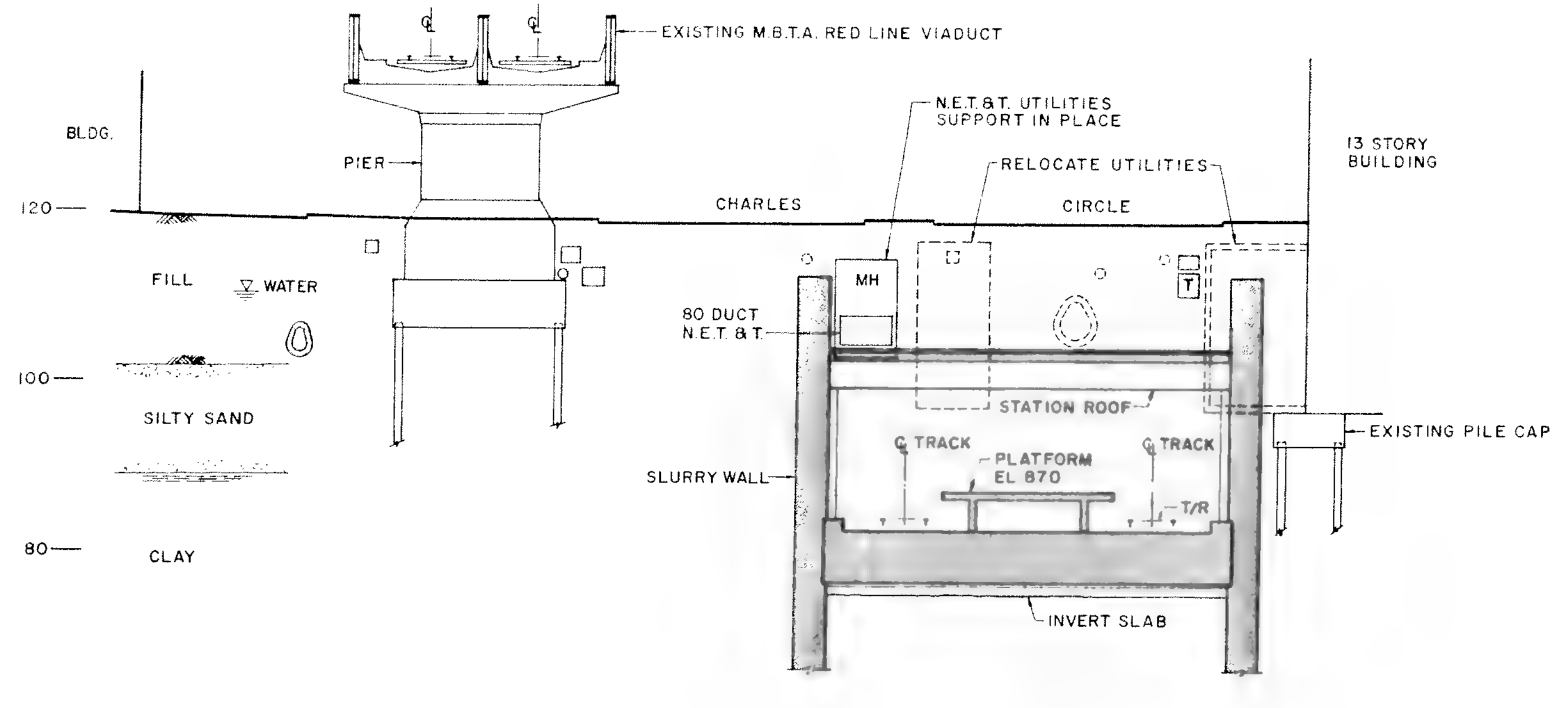


Bowdoin Station- Charles St. Station Connector Project - Feasibility Study

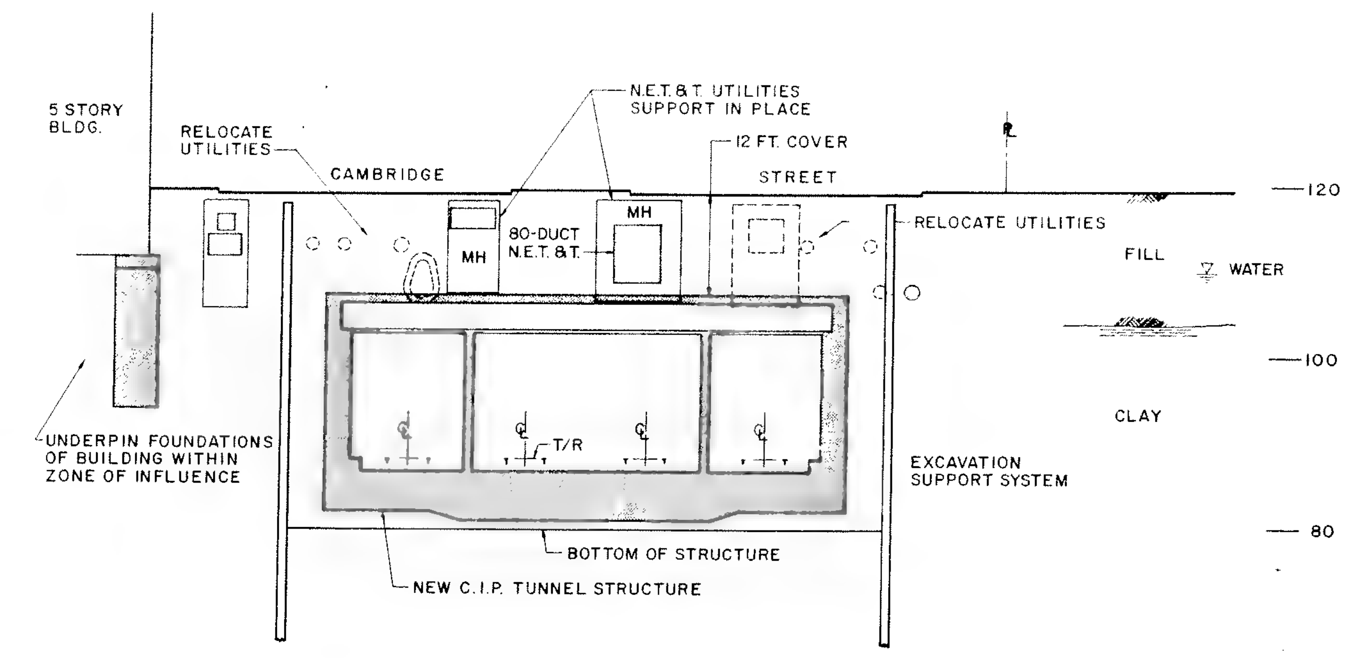
TUNNEL CONSTRUCTION METHOD

STV/Seelye Stevenson Value & Knecht
Engineers and Planners

FIGURE 14

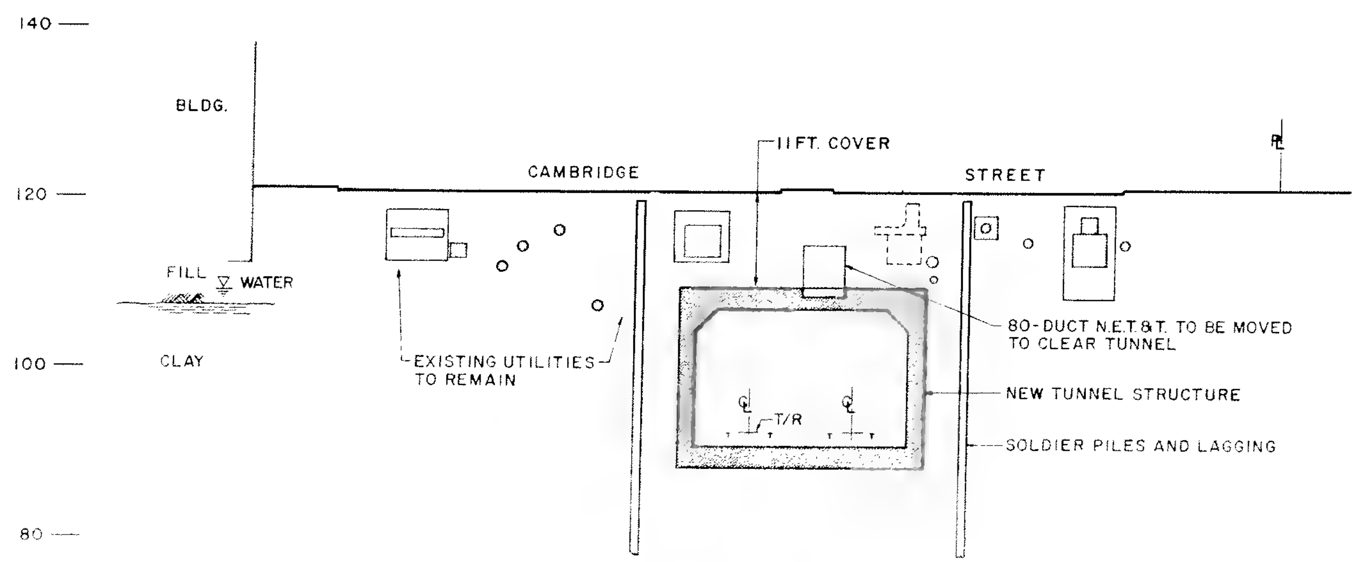


SECTION AT STATION - STA. 22+80



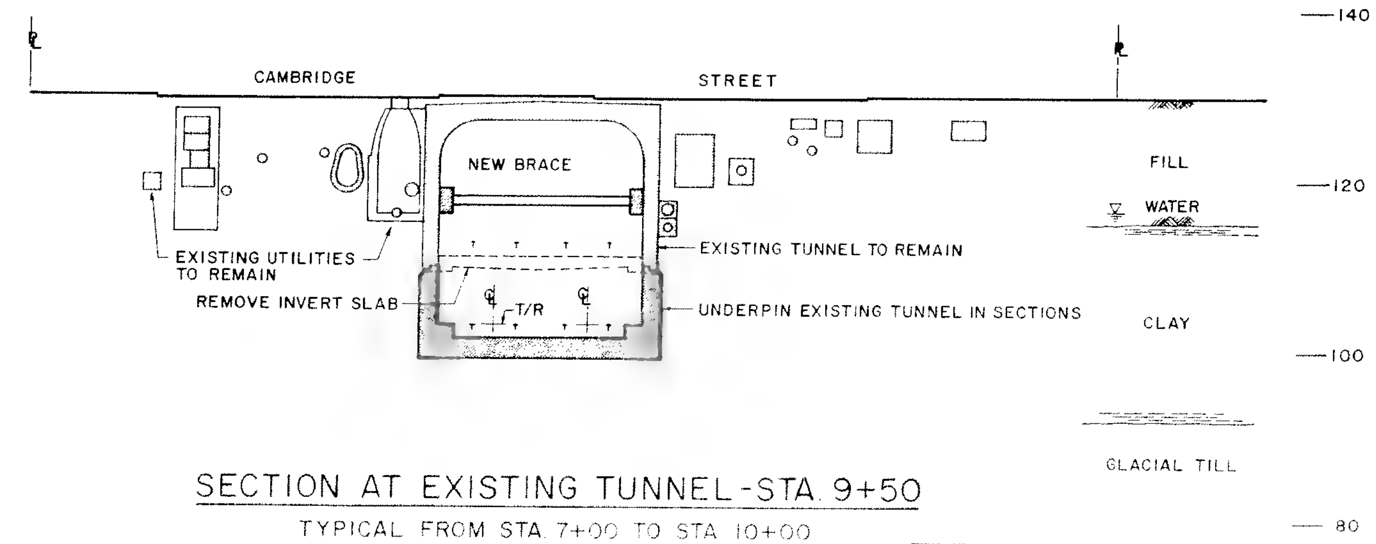
SECTION AT STORAGE TRACKS - STA. 17+00

TYPICAL FROM STA. 13+00 TO STA. 21+00



SECTION AT LINE STRUCTURE - STA. 12+00

TYPICAL FROM STA. 10+00 TO STA. 13+00



SECTION AT EXISTING TUNNEL - STA. 9+50

TYPICAL FROM STA. 7+00 TO STA. 10+00

0 8 16
SCALE IN FEET

Bowdoin Station - Charles St. Station Connector Project - Feasibility Study

TYPICAL SECTIONS

STV/Seelye Stevenson Value & Knecht

FIGURE 15

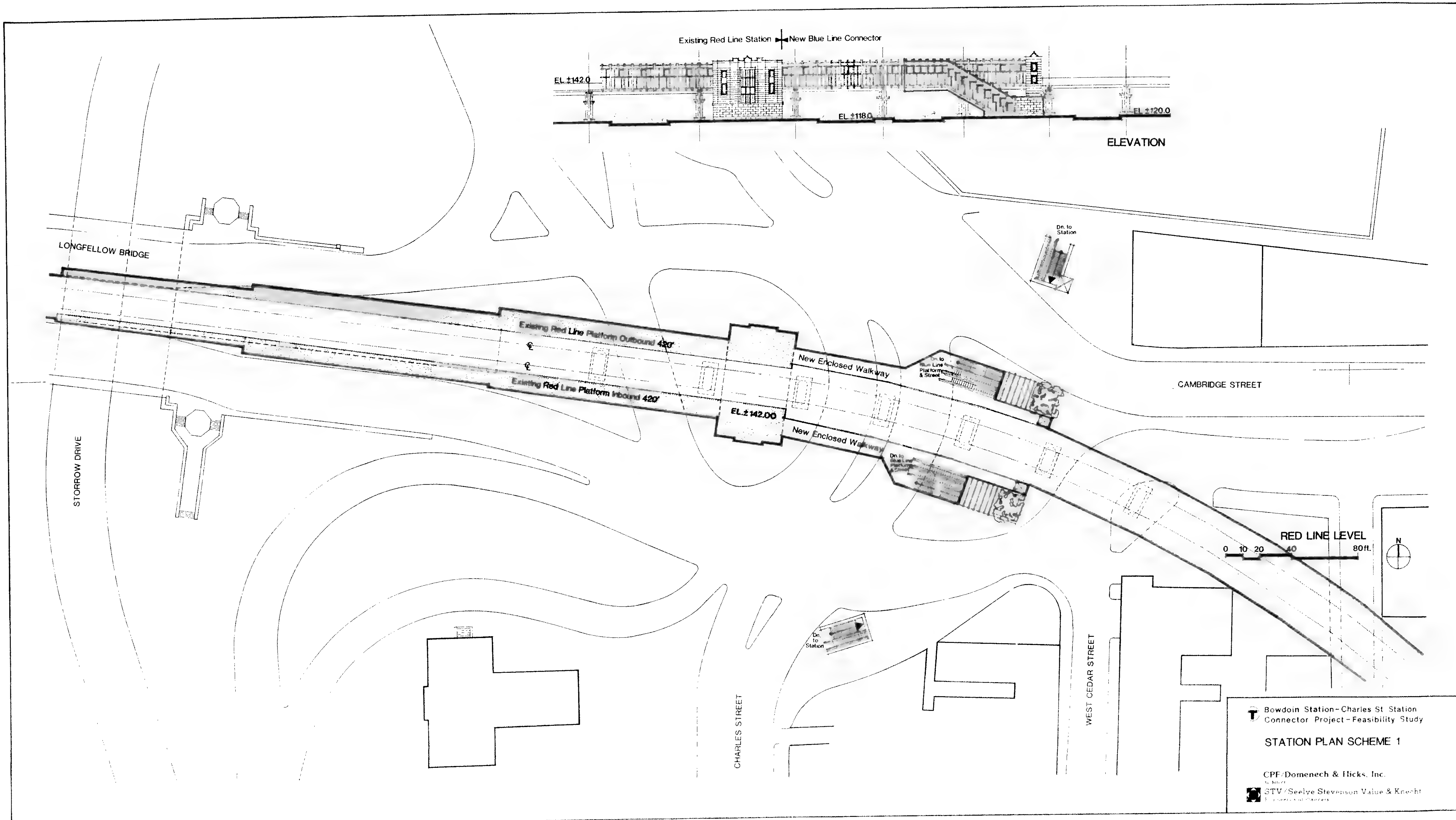
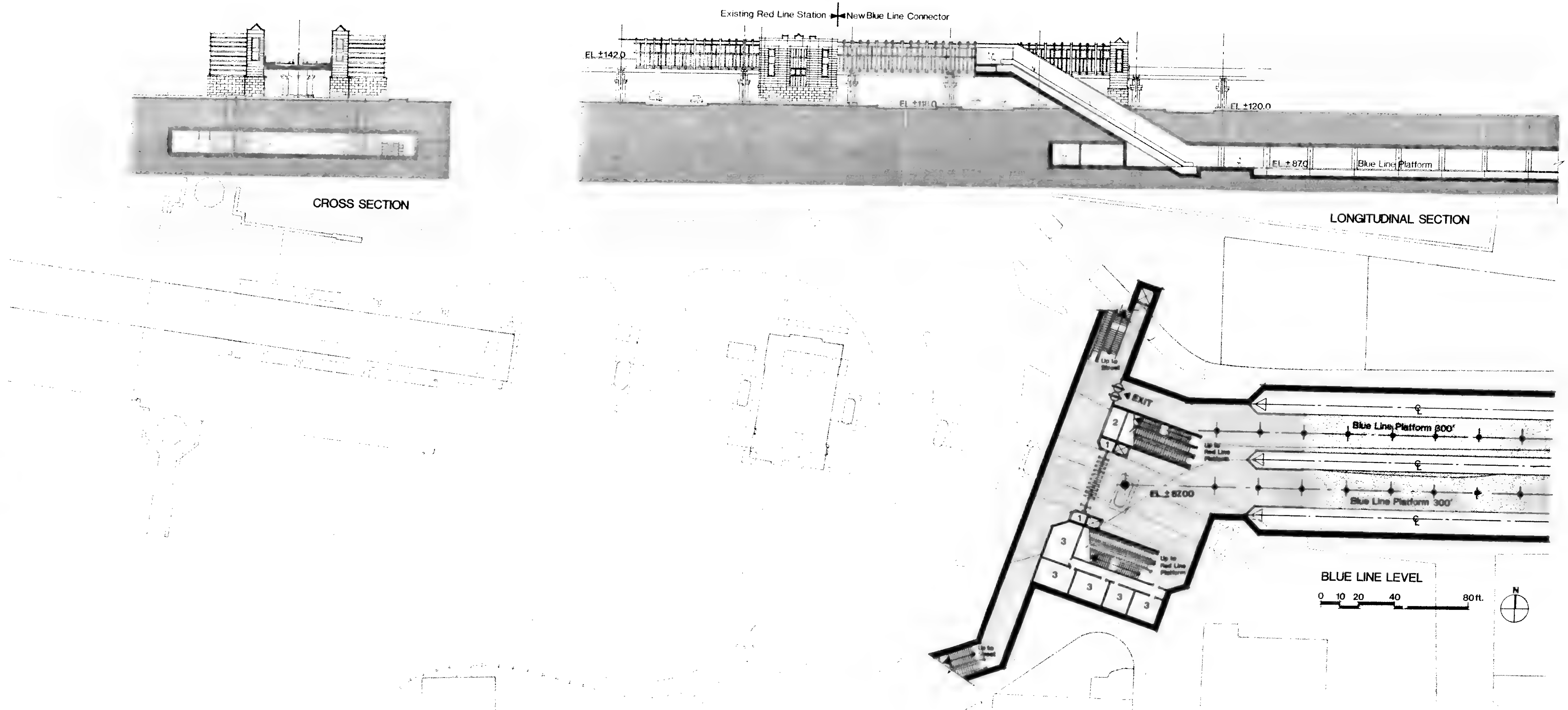

Existing Red Line Station
New Blue Line Connector
EL. ±142.0
EL. ±118.0
EL. ±120.0
ELEVATION
LONGFELLOW BRIDGE
Dn. to Station
Existing Red Line Platform Outbound 420'
Existing Red Line Platform Inbound 420'
New Enclosed Walkway
New Enclosed Walkway
EL.±142.00
CAMBRIDGE STREET
STORROW DRIVE
RED LINE LEVEL
0 10 20 40 80ft.
N
CHARLES STREET
WEST CEDAR STREET
Dn. to Station
Bowdoin Station-Charles St Station
Connector Project-Feasibility Study
STATION PLAN SCHEME 1
CPF/Domenech & Hicks, Inc.
STV/Seelye Stevenson Value & Knecht

FIGURE 16



LEGEND
1 Fare Collection Booth
2 Concession Space
3 Ⓣ Service Rooms

Bowdoin Station–Charles St. Station Connector Project–Feasibility Study

STATION PLAN AND SECTION
SCHEME 1

CPF/Domenech & Hicks, Inc.
STV/Seelye Stevenson Value & Knecht

FIGURE 17

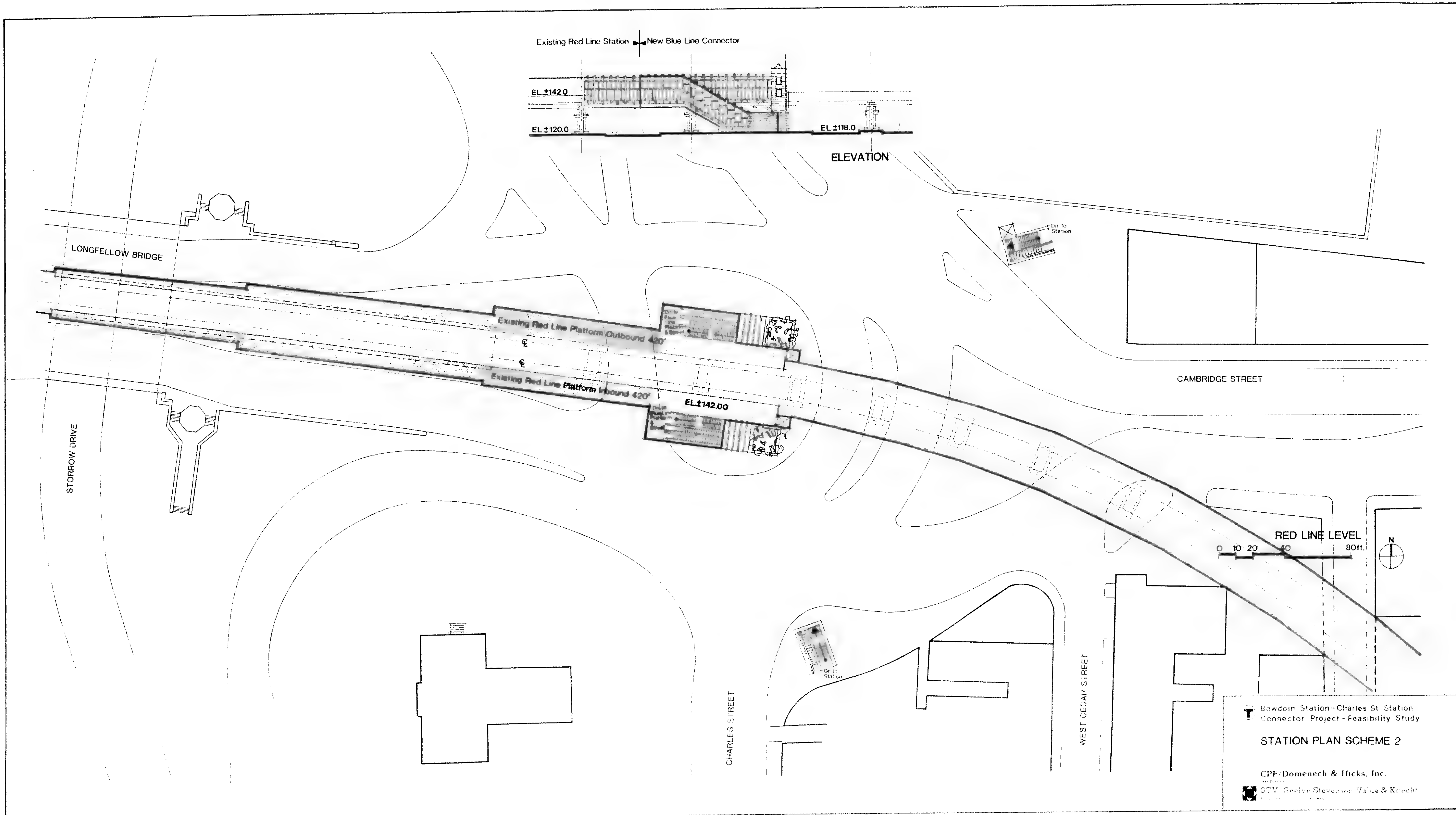

Existing Red Line Station
New Blue Line Connector
EL.±142.0
EL.±120.0
EL.±118.0
ELEVATION
LONGFELLOW BRIDGE
Existing Red Line Platform Outbound 420'
Existing Red Line Platform Inbound 420'
EL.±142.00
Dn. to Station
CAMBRIDGE STREET
STORROW DRIVE
RED LINE LEVEL
0 10 20 40 80ft.
N
CHARLES STREET
WEST CEDAR STREET
Bowdoin Station-Charles St Station
Connector Project-Feasibility Study
STATION PLAN SCHEME 2
CPF/Domenech & Hicks, Inc.
STV Seelye Stevenson Value & Knecht

FIGURE 18

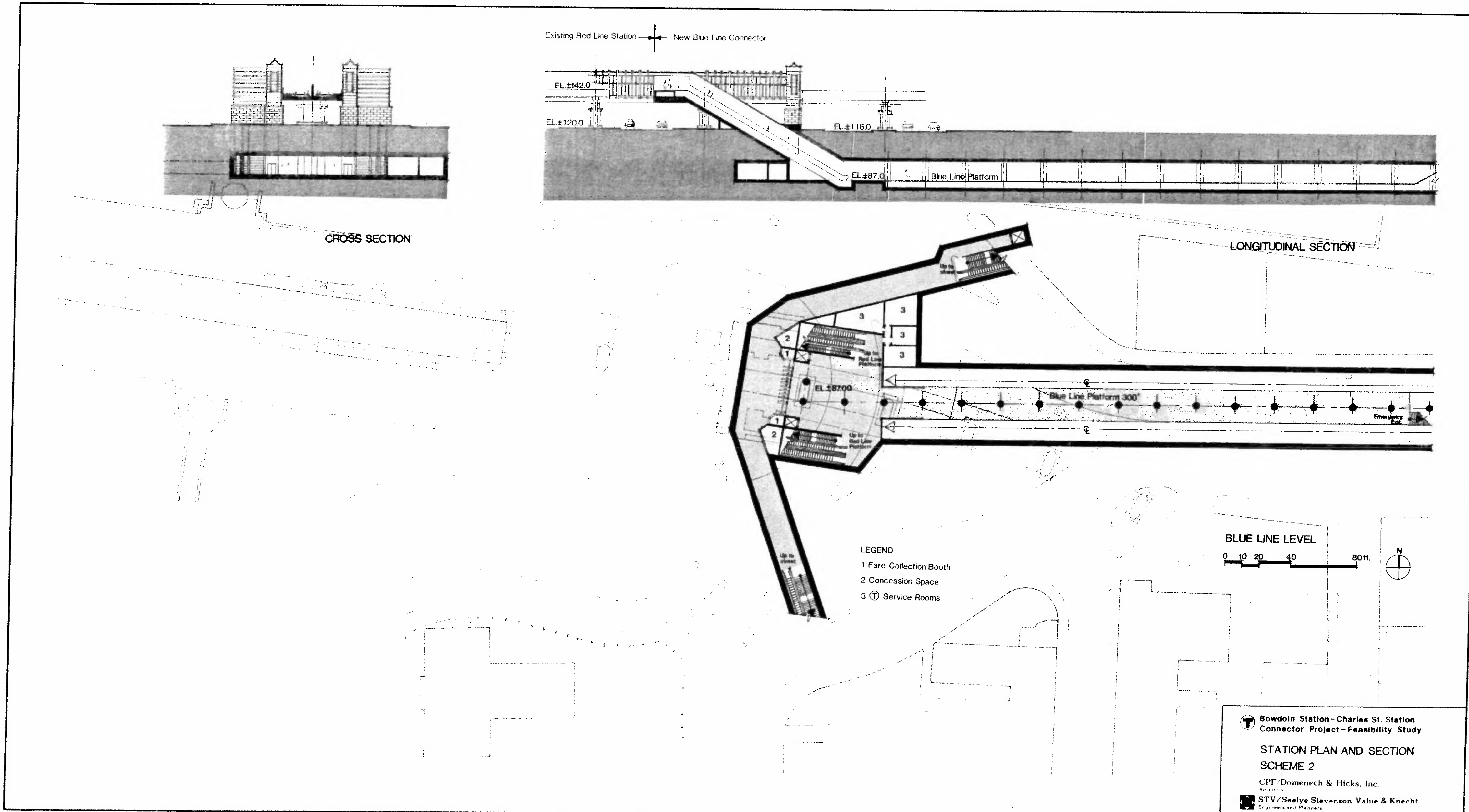

Existing Red Line Station
New Blue Line Connector
EL.±142.0
EL.±120.0
EL.±118.0
EL.±87.0
Blue Line Platform
CROSS SECTION
LONGITUDINAL SECTION
EL.±87.00
Blue Line Platform 300'
Emergency Exit
Up to Red Line Platform
Up to street
LEGEND
1 Fare Collection Booth
2 Concession Space
3 Ⓣ Service Rooms
BLUE LINE LEVEL
0 10 20 40 80 ft.
N
Bowdoin Station - Charles St. Station Connector Project - Feasibility Study
STATION PLAN AND SECTION
SCHEME 2
CPF/Domenech & Hicks, Inc.
Architects
STV/Seelye Stevenson Value & Knecht
Engineers and Planners

FIGURE 19

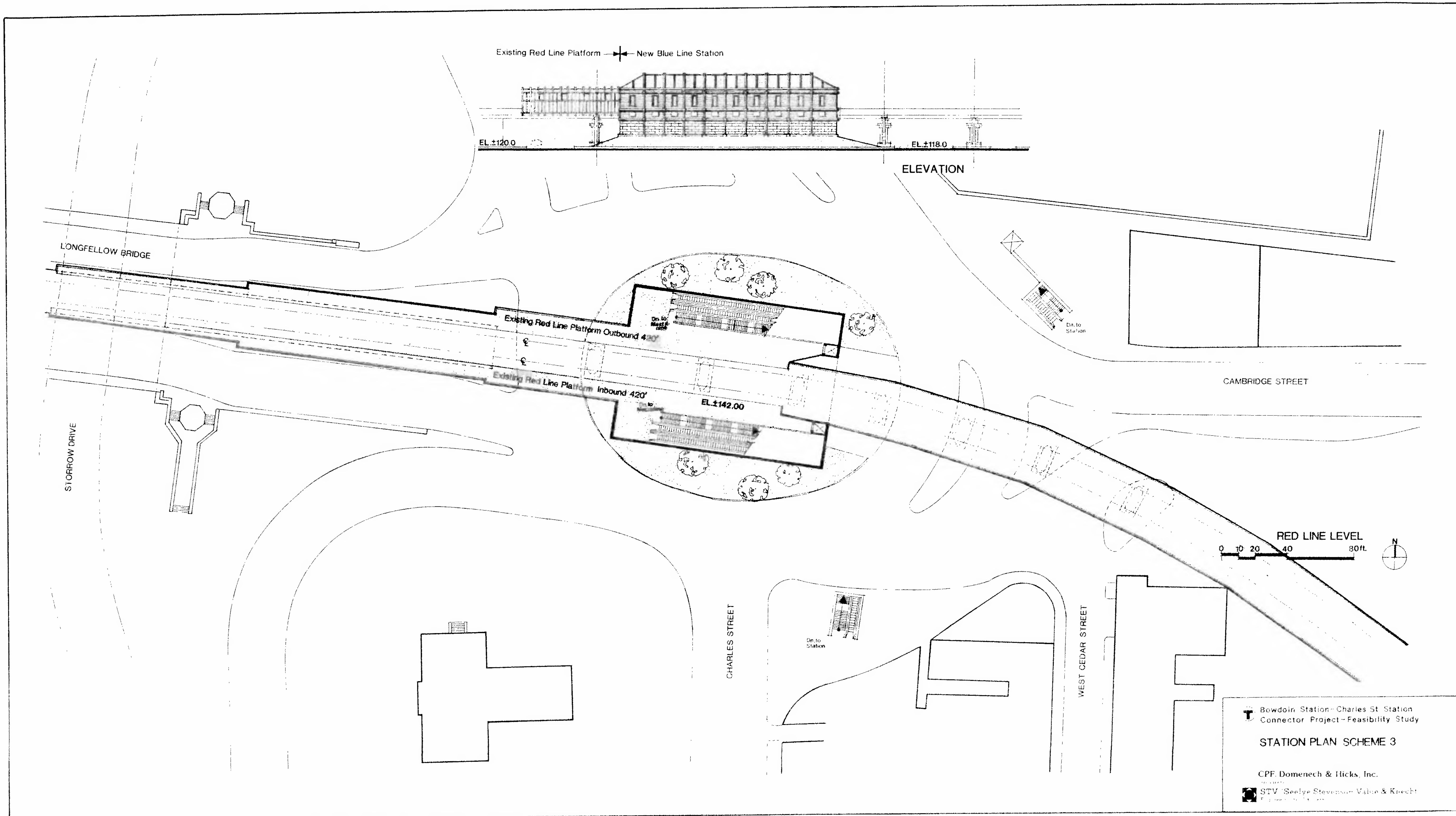

Existing Red Line Platform
New Blue Line Station
EL.±120.0
EL.±118.0
ELEVATION
LONGFELLOW BRIDGE
STORROW DRIVE
Existing Red Line Platform Outbound 420'
Existing Red Line Platform Inbound 420'
EL.±142.00
Dn. to Station
CAMBRIDGE STREET
CHARLES STREET
WEST CEDAR STREET
RED LINE LEVEL
0 10 20 40 80ft.
N
Bowdoin Station - Charles St Station
Connector Project - Feasibility Study
STATION PLAN SCHEME 3
CPF, Domenech & Hicks, Inc.
STV Seelye Stevenson Value & Knecht

FIGURE 20

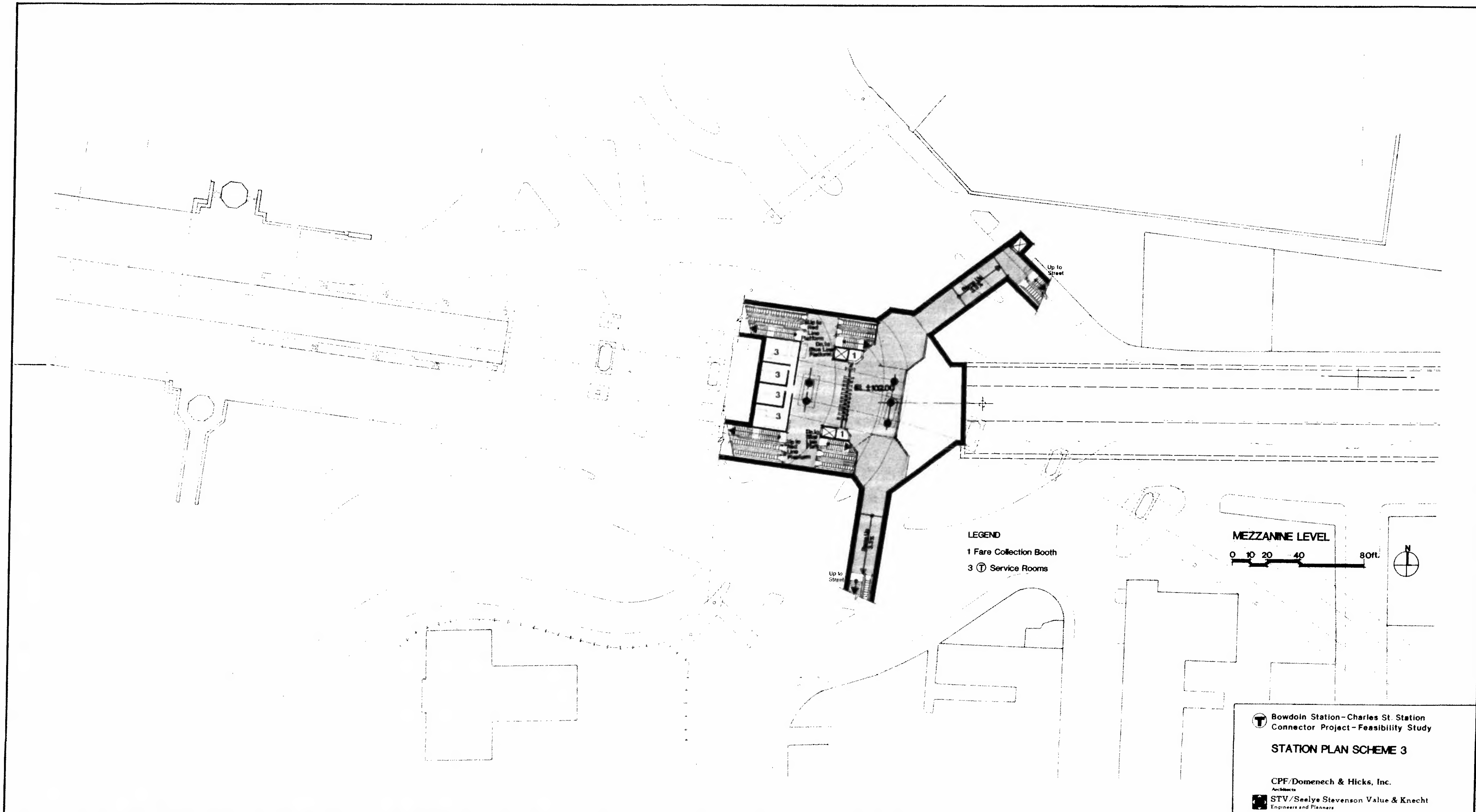
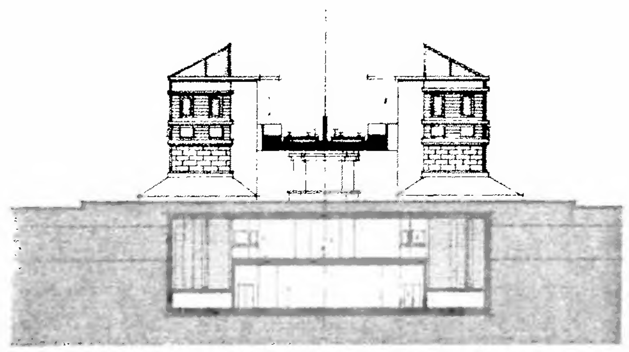
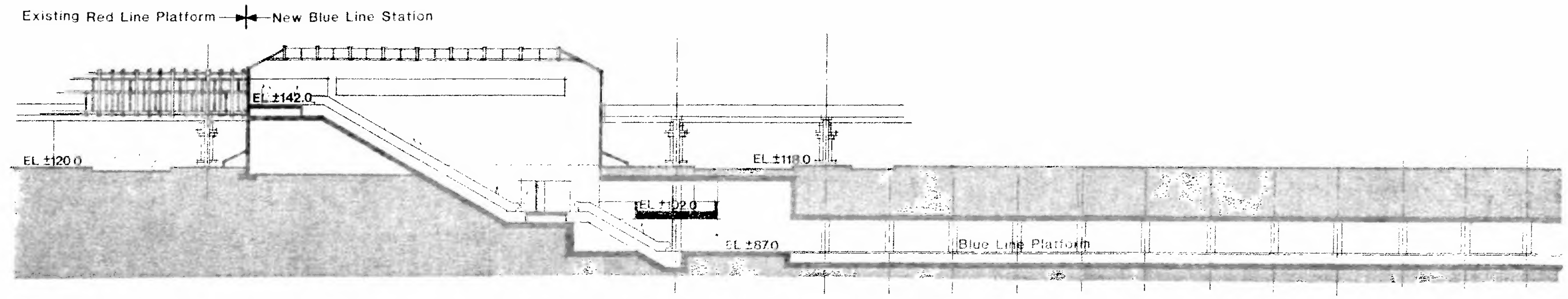

Up to Street
EL ±102.00
Up to Street
LEGEND
1 Fare Collection Booth
3 Ⓣ Service Rooms
MEZZANINE LEVEL
0 10 20 40 80ft.
N
Bowdoin Station-Charles St. Station
Connector Project-Feasibility Study
STATION PLAN SCHEME 3
CPF/Domenech & Hicks, Inc.
Architects
STV/Seelye Stevenson Value & Knecht
Engineers and Planners

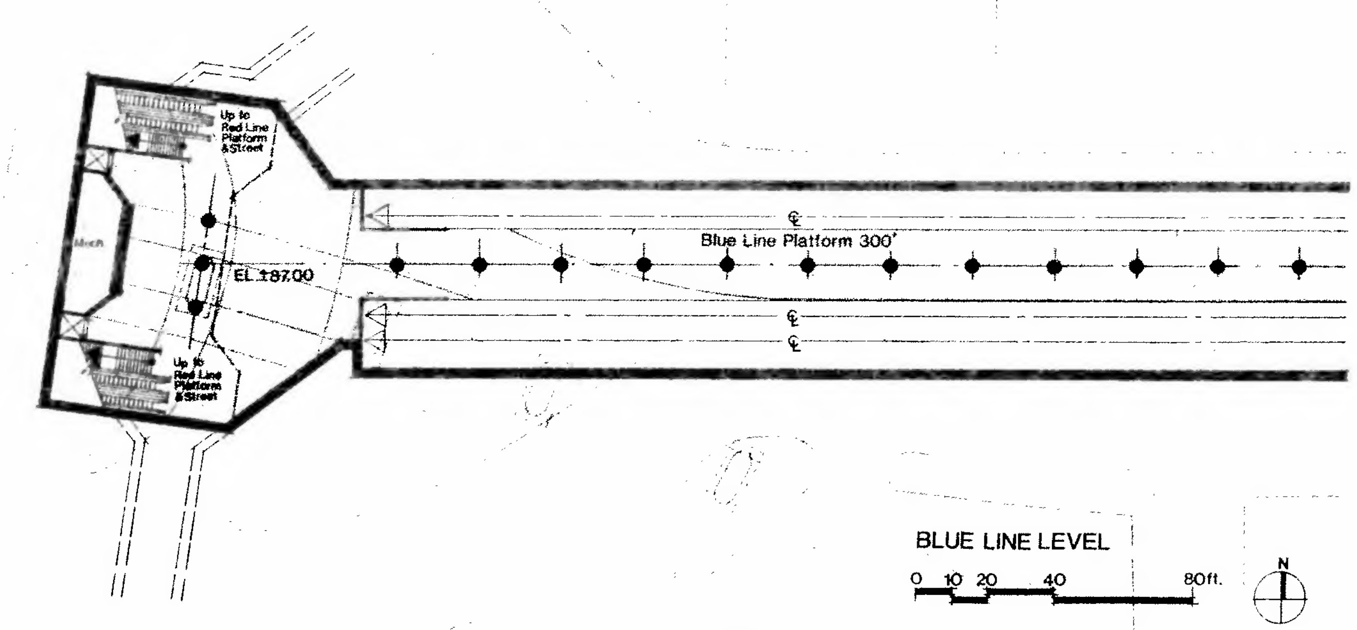
FIGURE 21



CROSS SECTION



LONGITUDINAL SECTION



Bowdoin Station–Charles St. Station Connector Project–Feasibility Study

STATION PLAN AND SECTION
SCHEME 3

CPF-Domenech & Hicks, Inc.

STV/Seelye Stevenson Value & Knecht

FIGURE 22